MOBILE CONCRETE SOLIDIFICATION SYSTEMS FOR POWER REACTOR WASTE

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ABSTRACT

In late 1988 SGN received an order from Electricite de France (EDF) for the construction of a mobile concrete solidification system to process secondary system resins generated by the P'4 and N4 series PWR power plants in France. This order was placed in view of SGN's experience with low- and medium-level radioactive waste treatment and conditioning over a period of almost 20 years. In addition to the construction of fixed waste processing facilities using more conventional technologies, SGN has been involved in application of the mobile system concept to the bituminization process in the United States, which led to the construction and commissioning of two transportable systems in collaboration with its American licensee US Ecology. It has also conducted large-scale R & D on LLW/MLW concrete solidification, particularly for ion exchange resins.

MIXING TECHNOLOGY DEVELOPMENT

Concrete solidification technology has been applied to spent ion exchange resins for many years in countries throughout the world at reactors, research centers and reprocessing plants. Changing specifications for storage of radioactive waste have, however, confronted the operators of such facilities with two types of very different problems :

- binder/resin interactions ;
- process application difficulties (unsuitable mixing methods, inaccurate metering, etc.).

With the support of EDF and Cogema, SGN has been performing in-depth research on concrete solidification of ion exchange resins (IERs) since 1983. This research has included the following :

- a general study on concrete solidification of reactor-generated resins ;
- a basic study of binder/resin interaction for reprocessing plants ;
- concomitant development and validation by EDF and Cogema of processes for three main IER types (IERs containing boron from primary water, secondary drains and treatment systems ; reprocessing IERs generated prior to fuel treatment ; reactor IERs used for purification of secondary system water treated with morpholine or ammonia).

This paper is specifically concerned with the conditioning of IERs used for purification of power reactor secondary system water.

The utilization technology developed simultaneously by SGN (which meant refining both process and technology) is based on the use of a highly efficient, stainless steel batch mixer. This mixer had previously been used in construction projects for ten years, as well as in the pharmaceutical and chemical industries. Its design was further refined on the basis of more than three years of pilot plant experience and the operation of a commercial system for five years at the Valduc production center of the French Atomic Energy Commission (CEA).

SGN's IER concrete solidification technology has been selected by Cogema for encapsulating spent fuel reprocessing resins and by EDF for conditioning French PWR secondary system resins.

The mixer is mainly characterized by the particular shape of its stirrer, which is located at the tank bottom. The stirrer transmits three successive movements to the product:

- slow horizontal displacement ;
- rapid rising ;
- helical fall in a vortex formed by the concave surfaces of the mixing paddle.

High efficiency and high encapsulating performances are achieved with this low-speed, yet high-energy mixing system. Mixing time is very short, i.e. less than 5 minutes.

The shape of the mixer, its construction material and its simple design ensure that almost none of the product is retained in the tank. In addition, its specially designed rinse system limits daily waste water production for a 250 liter mixer to 10 liters (with little solids content).

MAIN TECHNICAL ASPECTS OF THE MOBILE VLA WASTE SYSTEM

The mobile system selected by EDF and ordered from SGN for concrete solidification of resins from the PWR secondary system enables treatment of resins from eighteen P'4 and N4 PWR units, i.e. about 180 m^3 of resins per year. It is basically characterized by allowance for specific constraints, the most significant of which are :

- conditioning on some sites of resins saturated with ammonium ions, along with the preparation of encapsulated materials complying with standards issued by the French National Radioactive Waste Management Agency (Andra) without discharge of ammonia into the fixed processing facilities ventilation system ;

- systematic conditioning of resins with very low activity (VLA) concentration (less than 10^{-2} Ci/m^3) ; (Fig. 1)
- installation for operation in the waste treatment building controlled area bay ;
- extensive automation ;
- transportation between sites in compliance with standard road gauge specifications.(Fig. 2)

The system consists of a control console and three principal modules, one of which is designed specifically for pretreatment of ammoniated resins before their concrete solidification and for treatment of gases generated during this stage of the process. The three modules are made of a metal structure previously outfitted and provided with piping and wiring in the factory to minimize site connections and assembly/disassembly time. They are assembled and connected during the operating phase and rest on the floor of the waste treatment building bay in the power plants. (Fig. 3)

It should be emphasized that these structures comply with :

- the stringent 3.5 m height limit imposed for the P'4 reactor series to avoid obstructions of the crane in the bay during the operating phase ;
- standard road gauge limits for transportation between sites.

The concreting module includes the equipment required for performing basic operations, i.e. preparation of the concrete and filling of the drums. It consists of :(Fig. 4)

- a mixer with a 250 liter working capacity mounted on weighing devices ;
- an encapsulated materials pouring station ;
- a roller conveyor for handling empty and loaded drums.

At the start of a run, after the structure has been installed in the bay, the following operations are performed:

- installation of an auxiliary module consisting of a metal structure supporting a 150 liter resin metering pot ;
- mounting of a vibrating conveyor at the end of the main conveyor.

The empty weight of the concreting module is approximately 4 t and its dimensions are 3 x 2.2 x 3.45 m (lwh).

The dry blend module is a structure fitted with a vibrating frame that supports a removable cement bin. It also includes the power cabinet for the entire solidification system.

At the start of a processing run, the dry blend module structure is installed in the controlled area bay and aligned with the concreting module by means of centering plates. Its empty weight is about 1.5 t and its dimensions are 2.5 x 2.2 x 3.45 m (lwh).

The pretreatment module includes a metal structure that supports the equipment required for ammoniated resin pretreatment :

an agitated 1.5 m^3 tank capable of being heated and placed under negative pressure ;

- an agitated buffer tank ;
- a pretreatment reagent preparation tank ;
- a vacuum pump ;
- a venturi scrubber ;
- the associated transfer pumps.

Its empty weight is about 4 t and its dimensions are 3 x 2.2 x 3.45 m (lwh).

Connections between modules or between the system and the fixed facilities are made by hoses and quick connectors. The lines that carry the resins are fitted with self-obstructable quick connectors. The bottom section of the concreting and pretreatment modules is fitted with a stainless steel drip pan for collecting and retaining any leakage.

The three structures can be handled at the end of the bay where they are installed using a lifting beam. They are also provided with sleeves to enable handling by a fork lift truck available on the site, which ensures their unloading from the trailer truck. In this connection it should be stressed that the plant operator requires that the trailer remain outside the bay, which is a controlled area.

A 12.5 m long low-loading trailer is used to transport all the equipment. Before disassembly the equipment is rinsed and drained, and all openings are closed off. Prior to road transportation, all equipment placed on the flatbed of the trailer is covered with a leaktight tarpaulin.(Fig. 5)

Operation of the system centers around the mixer, which functions in batch mode and prepares in a single run the encapsulated material required to fill a 55-gallon metal drum.

The resins stored under water in the fixed facilities are pumped out in a water solution using a double-diaphragm pump driven by compressed air. They may be transferred :

- to the metering pot, where a semiautomatic sequence adjusts the water content of the resin volume required to prepare a batch of concrete ; or
- to the pretreatment tank in the case of the ammoniated resins.

Pretreatment eliminates all ammonia by low-pressure evaporation and displacement of the ammonium ions in a

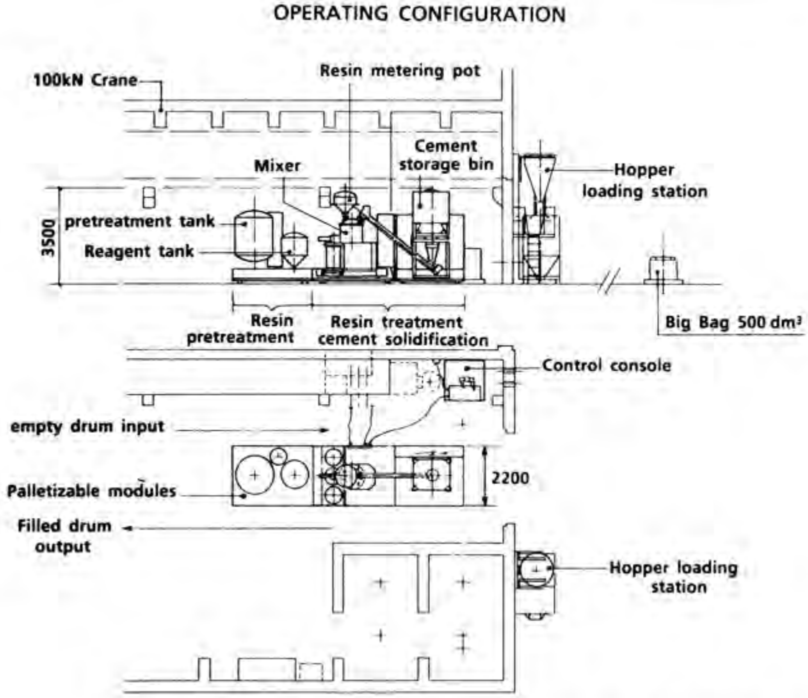

Fig. 1. Mobile Concrete Solidification System for VLA Waste.

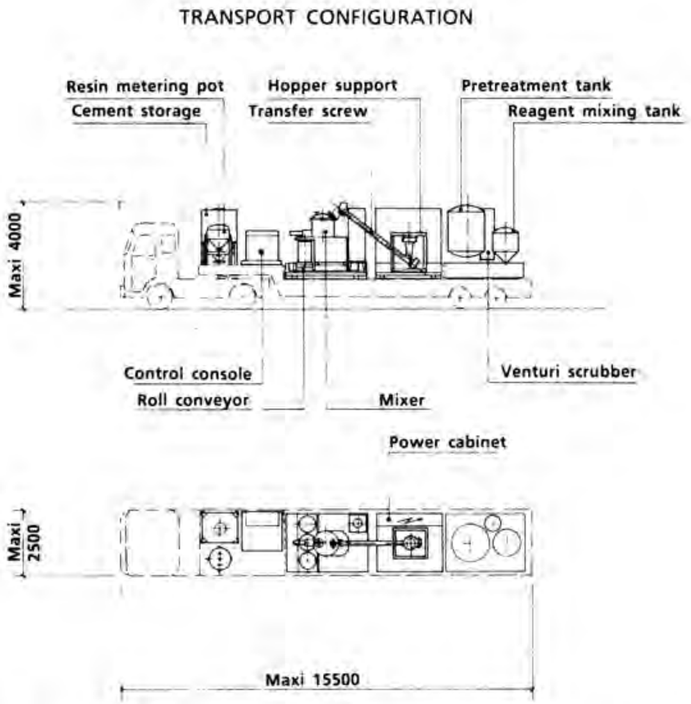

Fig. 2. Mobile Concrete Solidification System for VLA Waste.

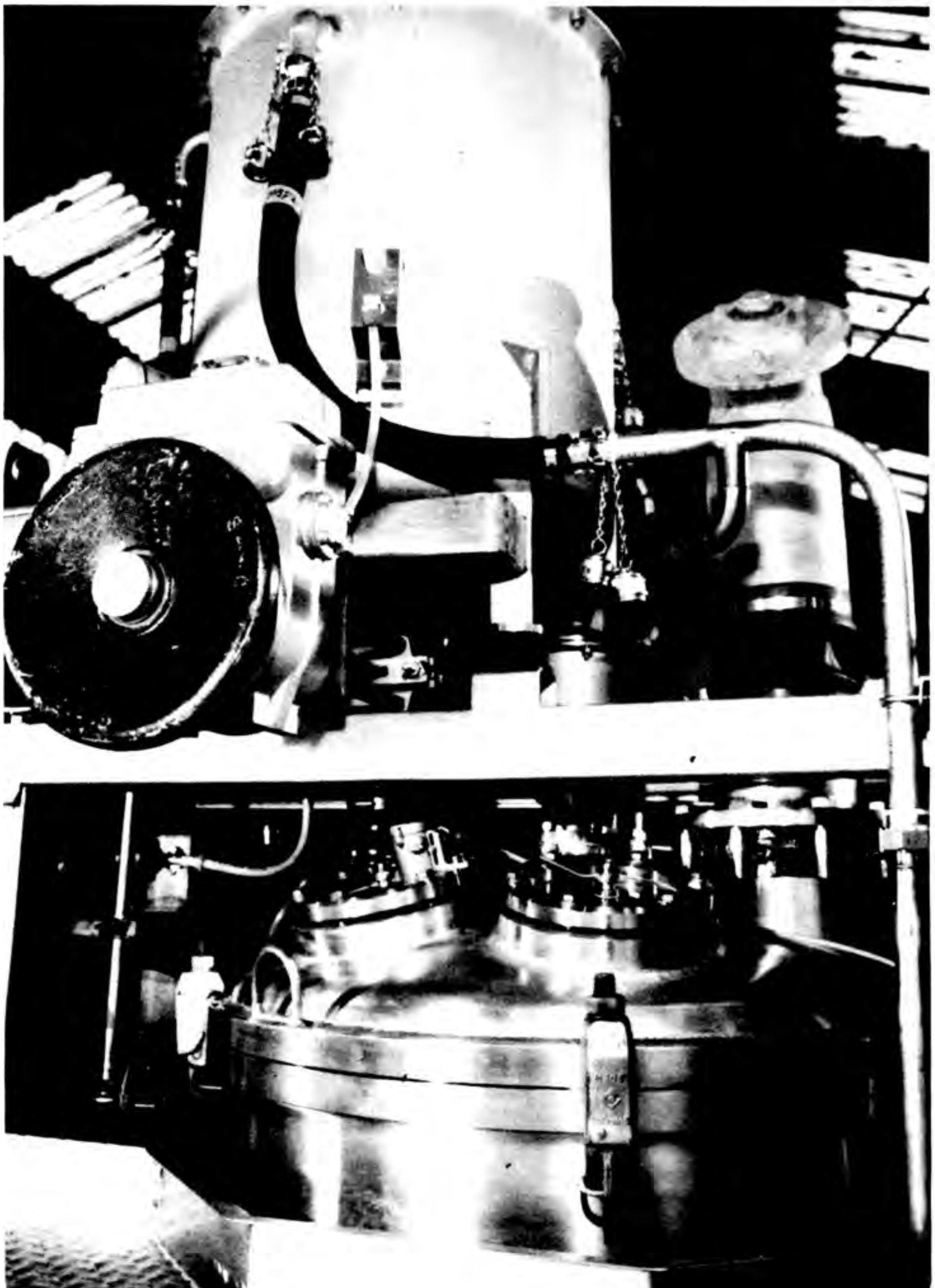

Fig. 3. Mobile Concrete Solidification System for VLA Waste.

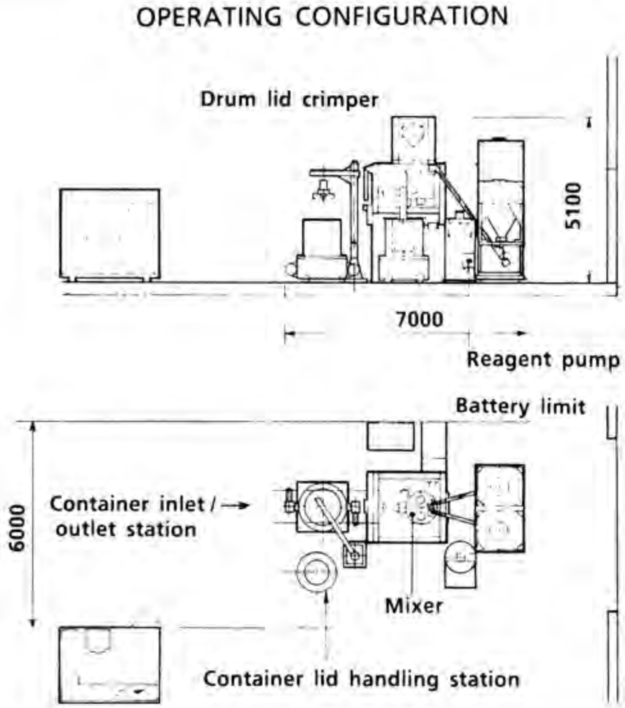

Fig. 4. Mobile Concrete Solidification System.

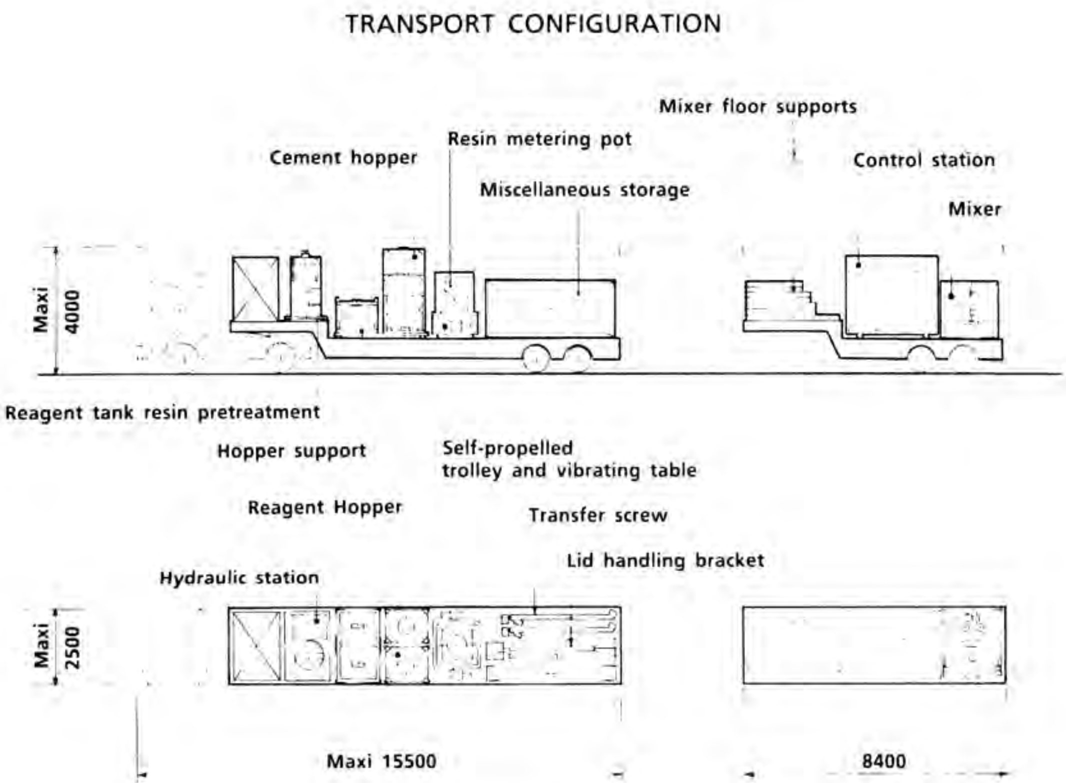

Fig. 5. Mobile Concrete Solidification System.

basic medium. The resins are then transferred to the metering pot using the same type of pump.

It should be noted that the ammoniated stream initially flows through a two-stage scrubber, which includes a jet-type venturi designed to condense and absorb the largest fraction of the flow, and a packing column. It is then purified in an active charcoal filter before discharge into a ventilation duct of the fixed processing facilities.

The metering pot operations include achievement of :

- a specified water content, i.e. fully decanted resins;
- a specified volume of resins for this concentration by passing the resin transport water through a strainer placed in an overflow pipe of the pot, while maintaining suspended resin feed.

Resin and supernatant levels are monitored during this operation by a camera through a viewing glass in the metering pot shell. The operator can thus monitor the changing resin concentrations until the resins/water interface also reaches the overflow pipe and so until the resins are fully decanted. This metered volume of resins is fully drained by gravity into the mixer.

The amount of cement required for preparing each batch is introduced into the mixer by a transfer screw connected under the cement storage bin. The screw is stopped automatically when the amount of cement predetermined by the operator is obtained. For this purpose, the mixer is mounted on a three-gauge weighing unit employed to precisely determine the weight of the encapsulated materials produced.

Drainage of the mixer is initiated by actuating a control that opens the hatch in the mixer bottom. The grout product is drained by gravity through a chute into the drum. A protective hood operated by pneumatic jacks is automatically placed on the drum before draining.

The drip tray, which is moved horizontally, collects any spilled products during drum changing operations. The metal drums are handled between lateral guide devices by a motor-driven roller conveyor with three separate work stations :

- an empty drum input station, where manual drum weighing is performed ;
- a pouring station ;
- a filled drum output station.

A collar-type lid is placed manually on filled drums before removal using a gripper vehicle.

The basic operations in this process are carried out and monitored by an operator at a remote control console located in the bay close to the system. The console is equipped with two mimic diagrams that display the concreting and pretreatment functions and enable monitoring each step as well as proper performance of the operations.

The system can handle resins from eighteen 1300 MWe PWR units, i.e. about 180 m^3 of resins with a volumetric encapsulation ratio of 40 to 75 %. The capacity of this plant is therefore about 1.5 m^3/day for one shift.

The system developed, which was supplied to EDF in late January 1990, will enable production of encapsulated material approved by storage authorities for all types of resin involved (cation, anion or combined cation/anion, with variable saturation rates). It will fill drums to an optimum level (95%), guarantee reproducible quality and permit easy, flexible operation with minimum maintenance requirements.

OTHER TYPES OF MOBILE SYSTEMS

In addition to this project distinguished more by the chemical properties than the radioactivity of the waste, SGN has performed several design studies for EDF and foreign utilities to develop mobile concrete solidification systems capable of processing radioactive waste that is substantially more radioactive, e.g. evaporator bottoms and reactor coolant system resins. As for the previously described systems, the key component in these systems is the mixer. By exploiting one of its primary characteristics, the total leaktightness of its tank, the mixer can contain liquids without any leakage, a highly advantageous feature which allows in-mixer pretreatment operations prior to any feeding of solid material ; it also prevents any splashing or external contamination.

The CEA selected this mixer to encapsulate alpha waste concentrates and sludges in its Valduc Center. The process was approved by French safety authorities and has been in use for five years.

Pretreatment is feasible for specific effluents in order to make them compatible with encapsulation into concrete or to improve the quality of the end product. This function could be performed directly inside the mixer or upstream from it in optional components.

These systems are also of modular design. They differ from the previously described systems, however, because they require radiological shielding in the form of painted steel panels fastened to the metal support structures.

The handling of the containers inside the system is also different and is usually carried out by a self-propelled vehicle equipped with a vibrating table. This vehicle, which is guided by rails laid on the floor, can accommodate heavier packages mainly consisting of 55-gallon drums placed inside recoverable metal containers that provide radiological shielding or, for EDF, concrete containers with a working volume of about 1 m^3.

Due to layout constraints and the 55-gallon drum requirement imposed by many plant operators, the mobile solidification systems developed had to be provided with mixers with a working capacity of 200 liters. The metal drums are filled in a single operation ; EDF's concrete containers are filled in several successive runs.

The annual volume of liquid waste produced in France by two reactor units (10 m^3 of boron-containing concentrates and 5 m^3 of decontamination waste) can be treated in one continuous five-day run. Located on the site in a controlled area bay, the systems employed are fully automated. All process and basic mechanical operations are conducted by an operator in a central control unit that can be installed near the system or even outside the bay where the system is located, according to customer requirements. A second operator is responsible for the fixed facility-mobile system interface and for the interface between the mobile system and the outside companies that supply the dry materials.

The modular design employed meets specific plant operator requirements and all the modules are usually shipped from one site to another on two standard-gauge road transport flatbed trailers. If necessary, the modules can be installed on an existing or specially built concrete structure, but the concreting system will still be fully tested in the assembly workshop and delivered practically ready for use.

CONCLUSION

SGN has addressed a new challenge for its technology in the field of low- and medium-level radioactive waste to combine high encapsulated material quality, low encapsulating material cost and modular design for mobile concrete solidification systems. The results obtained and the compatibility of the batch concreting process developed by SGN with the mobile system concept led EDF to adopt SGN technology for VLA IER concrete solidification using a mobile system that will be operational at the middle of February 1990.