TREATMENT OF SPENT FUEL POOL WATER FOR THE SAINT LAURENT A NUCLEAR POWER PLANT

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ABSTRACT

The Saint Laurent A nuclear power plant operated by Electricité De France (EDF) comprises two natural uranium-fueled, gas-cooled, graphite-moderated reactor (GCR) units that were shut down in 1990 and 1992. Final shutdown of the plant requires EDF to drain the spent fuel pools, rinse the pool walls and treat the effluent. EDF selected evaporation as the process to treat the effluent and commissioned SGN to build and operate an effluent treatment facility.

The effluent treatment facility has been installed on the edge of the unit 1 pool. It includes an evaporation unit, a concentrate cement solidification system, and a buffer storage vessel for the distillates, which are transferred via tank truck to the Saint Laurent B plant, which comprises two pressurized water reactor (PWR) units, for release. The evaporator is a kettle-type unit with a distillate purification column installed at the top. The treatment process includes an initial carbonate neutralization step through addition of nitric acid. After distillates are recovered in a condenser, their pH is adjusted in a pot. The evaporation unit has a capacity of around 900 l/h.

The effluent treatment facility was built between June and September 1999. Testing was conducted from October to December, and effluent treatment for the unit 1 pool began in January 2000. Approximately 1,130 m^3 of effluent were treated from January to July, representing around 80% of the pool water for unit 1.

In 2001, piping was installed to transfer effluent from the unit 2 pool to the unit 1 pool, and to transfer the effluent contained in storage tanks directly to the evaporation unit.

Following completion of this work, the evaporation runs resumed in December 2002 to complete the treatment of unit 1 pool water, and to treat the pool water of unit 2 after transfer to the unit 1 pool, as well as the effluent contained in the storage tanks.

Approximately 2,900 m^3 of effluent has been treated to date, resulting in the production of around 157 m^3 of concentrate. The purification factor of the evaporator exceeds 200,000, and distillates are produced within the specified discharge limit. Properties of the concentrate comply with requirements for the cement solidification process. Following an adjustment period at the start of effluent treatment for unit 1, the evaporation unit is operating at rated capacity.

INTRODUCTION

The Saint Laurent A nuclear power plant operated by Electricité De France (EDF) comprises two natural uranium-fueled, gas-cooled, graphite-moderated reactor (GCR) units that were shut down in 1990 and 1992. Final shutdown of the plant requires EDF to drain the spent fuel pools, rinse the pool walls and treat the effluent. EDF selected evaporation as the process to treat the effluent and commissioned SGN to build and operate an effluent treatment facility.

WASTE TREATED

The effluent to be treated is the unit 1 fuel pool water (1,400 m^3) , the unit 2 fuel pool water (1,400 m^3), the two G tanks effluent (310 m^3) and the TEL tank effluent (190m^3). The effluent contained in the tanks is fuel pool water which has been clarified and filtrated.

The effluent has the following compositions :

Table I Chemical composition of effluent

Chemical analysis	Unit 1 fuel pool water	Unit 2 fuel pool water	G tanks	TEL tank
pH	9.3	11	9.5	9.7
Na^+ (g/l)	12	11	2,1	6.9
CO_3^{2-} (g/l)	3.1	14	1.5	2.5
Cl^- (mg/l)	-	7	50	150
Mg^{++} (mg/l)	47	45		
Dry material (g/l)	40	30	7	23

Table II Radiological activity of effluents

Activity (Bq/l)	Unit 1 fuel pool water	Unit 2 fuel pool water	G tanks	TEL tank
alpha	3 800	1 300	6 900	650
beta	255 000	238 000	123 000	170 000
gamma	66 000	107 000	66 000	145 000

Pool water has been filtrated prior to evaporation.

PURPOSE OF THE TREATMENT

The effluent treatment should produce :

- Concentrates with a salt content of 640 g/l enabling their cementation through EDF embedding process
- Distillate complying with the release standards.

As they are drained the pool walls will be decontaminated and the tanks G and TEL will be rinsed after draining.

TREATMENT PROCESS

The treatment process is shown in the following diagram (Fig. 1).

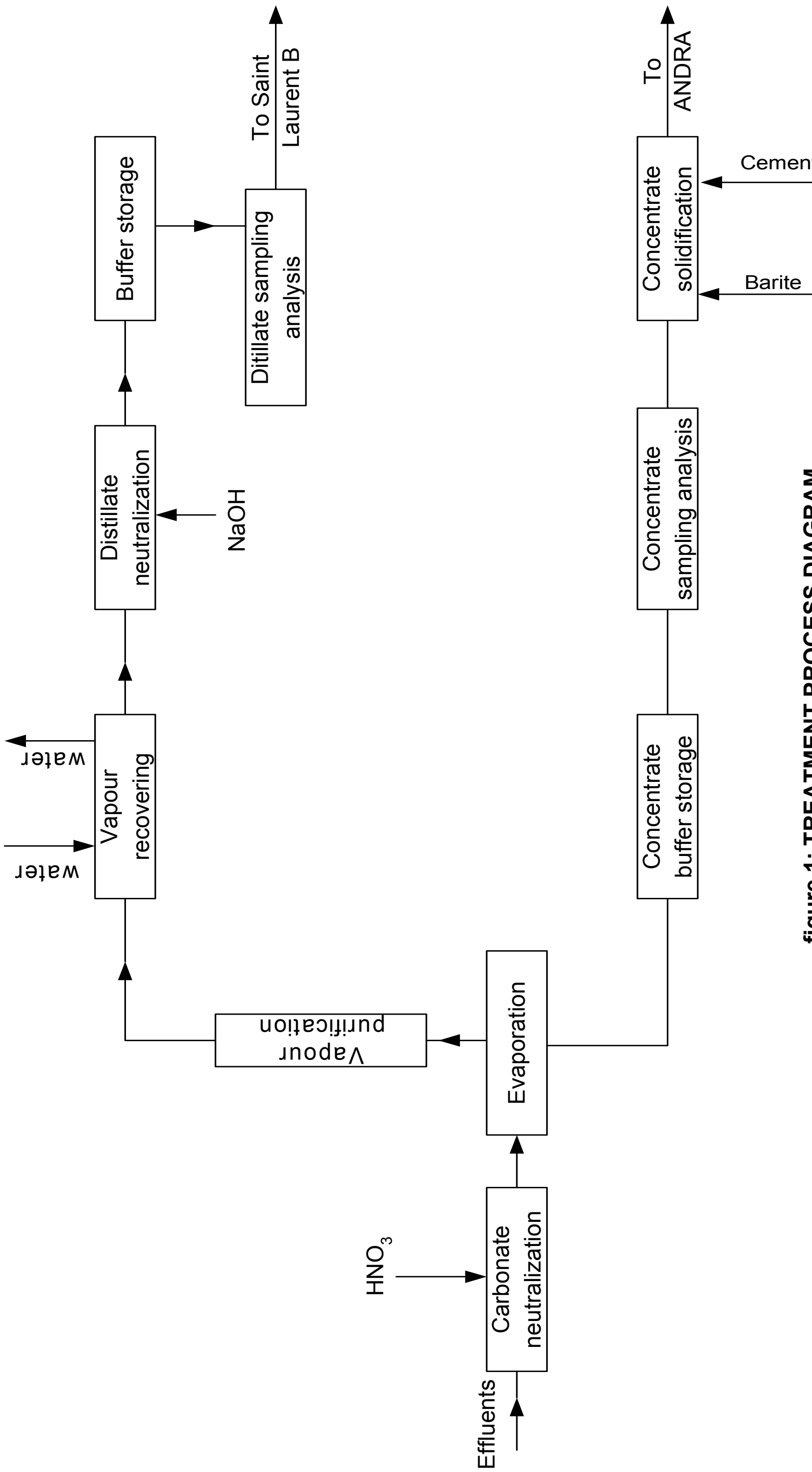

figure 1: TREATMENT PROCESS DIAGRAM

EVAPORATION CAMPAIGN

The pool water is treated either separately (pool water of unit 1) or at the same time as the water from tanks G (pool water of unit 2).

In the latter case the weekly evaporation campaigns begin with the pool water which brings the salts necessary to ensure the concentrate salt content and end with the effluents of tanks G which increase the chloride content.

The effluents contained in tank TEL are treated separately. Taking into account their high chloride content these effluents are evaporated at a pH = 10 which reduces the corrosion risk of stainless steel.

EVAPORATION PROCESS

Carbonate neutralization

The effluent concentration cannot be achieved without a preliminary chemical treatment due to the low solubility of carbonate salts in water. For this reason, carbonate salts are neutralized with nitric acid before introducing the effluents into the evaporator vessel.

The carbonate neutralization of pool water and of the effluent contained in tanks G is carried out in the evaporation unit. Nitric acid is added in-line to the effluents in order to obtain a pH lower than 2, the effluents then flow out in the evaporator.

The carbonate neutralization of effluents contained in tank TEL is carried out in the tank itself. Soda is added in-line to the decarbonated effluents in order to obtain a pH higher than 10 and to enable their evaporation while reducing the risk of corrosion.

Evaporation

The evaporation is performed in a kettle type evaporator of a useful volume of 4.2 m^3, with electrical heating (output : 640 kW). The water level in the evaporator is maintained constant at its set value by modifying the effluent flowrate introduced into the upstream neutralization tank.

A double jacket helps to cool the concentrates at the end of the campaign via a heat exchanger with cooled distillates circulating inside the double jacket.

Vapours scrubbing

Vapours are scrubbed through two wire-mesh eliminators and then through a column with 5 bubble plates. The bubble plate column and the mist eliminators are sprayed permanently.

Vapours condensation

At the column outlet the vapours are condensated in a tubular water cooled condenser.

Distillate neutralization

The distillates are neutralized with soda so as to comply with the release standards. Neutralization is performed by addition of soda.

Distillate storage

The distillates are stored in two 20 m^3 tanks.

A sampling is carried out in the second tank and sent to the site laboratory for radiological and chemical analysis.

After checking that results are in accordance to the release standards, the distillates are transferred via a tanker to Saint Laurent B which ensures the release.

Concentrate storage
The evaporator salt content is monitored in the evaporator through density measurements .

When the requisite salt content is not reached at the end of the week the level inside the evaporator is reduced until obtaining the requisite value. At the end of each weekly evaporation campaign the concentrates are cooled thanks to the circulation of cooled distillates through the double jacket.

A sample taken in the evaporator allows to confirm that the requisite concentration is reached.
The concentrates are then transferred into a buffer tank by means of a pump.

Concentrate cementation
The concentrates are sent via a pump into the cementation unit mixer placed on three load cells. When the quantity transferred reaches 240 kg (nominal quantity) the mixer is started to mix the concentrate with barite to obtain a pH higher than 7.
Cement is then added and mixed with the neutralized concentrates.
The batch is then emptied into a metal box of a useful capacity of 2440 l.
Around 9 batches are necessary to fill the box.
After setting of the mortar the box is coated with polyurethane and placed into a 5 m^3 cubic fiber concrete container before being transferred to ANDRA storage center.

CAPACITY OF THE EVAPORATION UNIT AND OPERATING MODE

The evaporation unit is operated continuously from Monday morning to Friday morning. The evaporator control is automatic and the operators intervene to control the start-up and shutdown of the evaporation campaign, to adjust the level inside the evaporator or to perform specific tasks such as the tanks filling with acid or soda or to perform sampling.

The evaporation capacity is around 900 l/h which corresponds to 720 l/h of effluents taking into account the addition of nitric acid and the spraying of the mist eliminators and the column.

POOL DECONTAMINATION

For each reactor unit a confined area covering the pool is installed. This area is placed under negative pressure with respect to the pool hall. Straight openings are arranged in the roof so as to enable the equipment transfer by means of the 20 kN travelling crane of the pool hall.

The working areas are constituted by a metallic frame supporting translucent panels. Each working area is provided with personnel access and exit airlocks and with an equipment access airlock. The decontamination operations are carried out by an operator from a working platform floating over the pool water.

The immersed walls are rinsed with pressurized water. After decreasing of the water level the emerged walls are decontaminated using rags impregnated with a decontaminating material.
A second operator placed at the pool edge ensures the movements of the floating platform and its

monitoring. The purpose of the decontamination operations is to ensure a labile contamination level lower than 4 Bq/cm^2 in beta-gamma. When this objective is met the walls are painted.

LAYOUT

The evaporation unit is installed in the pool hall at the edge of reactor pool unit 1 in the near vicinity of the working area covering the pool.

The unit is comprised of three skids provided with drip trays :

- The effluent neutralization skid with the nitric acid tank (1500 l), the weighing vessel (100 l) and the condenser

- The evaporator skid with the evaporator, its column and two concentrate transfer pumps

- The distillate neutralization skid with the soda tank (1500 l) and the distillate return pipe to the evaporator double jacket.

The concentrate storage tank is installed in a pond located under the evaporation skid. The cementation unit is installed in the cask unloading hall near the pool hall. This unit is comprised of the mixer placed on three load cells, the cement hopper and its feed screw, the barite hopper and its feed screw.

The cementation unit is located in a working area under negative pressure with respect to the cask unloading hall. This working area is comprised of a metallic frame supporting translucent panels and is provided with access airlocks for both the personnel and the equipment.

The two distillate storage tanks are installed in a new building fitted with wall cladding built near the pool hall.

KEY MILESTONES

The effluent treament unit was erected from June to september 1999. The inactive tests were performed from September to November 1999 and the active tests were performed in December. The treatment of unit 1 pool water started in January 2000. Between January and July 2000 aroud 1130 m^3 of effluents have been treated representing nearly 80% of the unit 1 pool water. It was then decided to treat the pool water of unit 2 using the pool of unit 1 as a buffer tank. Furthermore EDF asked SGN to treat the effluents contained in tanks G and TEL.

In 2001, piping was installed to transfer effluents from the unit 2 pool to the unit 1 pool, and to transfer the effluents contained in storage tanks directly to the evaporation unit. Following completion of this work, the evaporation runs resumed in December 2002 to complete the treatment of unit 1 pool water, and to treat the pool water of unit 2 after transfer to the unit 1 pool, as well as the effluents contained in the storage tanks. Approximatively 1770 m^3 of effluents have been treated from December 2002 to October 2003.

EXPERIENCE FEEDBACK

Volume reduction and load factor

The treatment of 1130 m^3 of pool water of unit 1 has produced around 77 m^3 of concentrates which after conditioning for storage represent 260 m^3 of packages, that is to say an overall volume reduction factor of 4.35.

Treatment has been carried out within 26 weeks (among which 21 weeks of actual evaporation with a load factor over 80 %). The treatment of 1770 m^3 of unit 2 pool water and of the effluents contained in tanks G has produced aroud 80 m^3 of concentrates which after conditioning for storage represent 270 m^3 of packages, that is a volume reduction factor of 6.55. The treatment has been carried out over 32 weeks (among which 28 weeks of actual evaporation with a load factor over 95 %).

Evaporation unit

At the beginning of unit 1 pool water treatment some sections of the pipe containing concentrates were clogged by sodium nitrate crystals. To prevent this drawback, modifications have been made on the tracing and heat insulation of these pipes. Furthermore all pipes containing concentrates have systematically been rinsed with the pool water after use. During the treatment of unit 1 pool water disparities have been observed between concentration measured either via the density or via the temperature in the evaporator and that measured on the sample taken after transfer into the concentrate tank. In order to avoid any untimely transfer of the concentrates the evaporator instrumentation has been completed (additional temperature measurement) and a sampling circuit has been installed in the evaporator.

In addition, the measurement of the dry extract contained in the sample is carried out in a ventilated enclosure and no ventilated protective suit is required to perform this measurement. These improvements have been made before treating the pool water of unit 2. The distillates have always been in accordance to the release standards except for a batch for which the spraying of a wire-mesh eliminator had been stopped. The purification factor of the evaporator is higher than 200,000.

Cementation unit

The operating of the cementation unit progressed without significant incident during the treatment of unit 1 pool water. At the beginning of unit 2 pool water treatment the mixer drain valve, which is a diaphragm valve, broke four times for various reasons : material ageing, etching, mechanical stress. Further to these breaks an inspection of the valve diaphragm is now performed after each cementation campaign and the diaphragm is replaced if necessary.

DECONTAMINATION OF THE POOL WALLS

The decontamination of the pool walls, as they are drained, from a working platform floating over the pool water progressed without difficulty. There is still 50 cm of water in each pool (initial level : unit 1 = 6.20 m ; unit 2 = 6.40 m). The dose rate increased significantly near the pool bottom.

The following operations have been planned to treat the pool bottom :

- Remote recovering with a griper of some bulky waste remaining at the pool bottom
- Recovering the small waste by suction and filtration
- Measuring the residual dose rate after these cleaning operations

The draining will then be continued and the pool bottom will be subject to the same decontamination as the walls.

CONCLUSION

SGN has treated 2,900 m^3 of effluents through the evaporation process wich represents nearly 90 % of the requirements. The evaporation unit operates satisfactorily at rated capacity, with a load factor over 80 % and produces distillates with a cleanup factor higher than 200,000. The cementation unit has operated satisfactorily during the treatment of unit 1 pool water. Several breakages of the drain valve diaphragm of the mixer occured at the beginning of the treatment of unit 2 pool water leading to a new inspection procedure of the mixer. The decontamination of the pool walls progressed satisfactorily. The treatment of the pool bottom part requires the implementation of specific measures. The treatment in alkaline phase of effluents contained in tank TEL has to be performed.