INDUSTRIALIZATION OF A COMPACT SLUDGE RETRIEVAL SYSTEM

J.-J. Pielawski, N. Hubert
SGN, 1 rue des Hérons, Montigny-le-Bretonneux, 78 182 Saint Quentin-en-Yvelines Cedex, France

C. Gawron
SGN, HRB, 33 rue d'Aurigny, 50 440 Beaumont Hague, France

M. Duret
COGEMA, Etablissement de La Hague, 50 444 Beaumont La Hague Cedex, France

ABSTRACT

The Compact Sludge Retrieval system (CSR system) has been industrialized by COGEMA, for retrieval of sludge waste, from STE 2 storage silos at UP 2 reprocessing plant at La Hague, France.

STE 2 is a liquid waste treatment facility which was operated by COGEMA from 1966 to 1998. The facility treated low- and intermediate-level liquid waste produced by UP 2 reprocessing plant. Sludge produced by liquid waste treatment was stored in waste storage silos. The scope of the STE 2 sludge retrieval and conditioning project is to retrieve, transfer and bituminize approximately 9,000 m^3 of sludge from seven STE 2 waste storage silos, which have a total radioactive content of 70,000 TBq of beta-gamma emitters and 3,400 TBq of alpha emitters. The sludge dry content (3,300 tons) includes 82 % of precipitated salts and 18 % of soluble salts, such as sodium nitrate.

While the bituminization is already in operation in the STE 3 facility, retrieval of STE 2 sludge is a new industrial operation for the La Hague site. It has been designed and planned with great care to provide COGEMA with an effective, reliable and cost-effective retrieval system.

To ensure success, the components of the CSR system were tested, using simulated waste, in a mock-up test facility at the Beaumont Research Laboratory, which proved the principle was valid.

The lessons learned from these cold tests were applied to the final design of the CSR system which was subsequently deployed in a STE 2 silo, silo 550-14, in 2002. Sludge waste retrieval operations conducted in silo 550-14 were considered hot tests for the CSR system. These hot tests proved successful and are now followed by industrial implementation at the STE 2 facility and at the Tchernobyl Liquid Radwaste Treatment Plant (LRTP), Ukraine.

INTRODUCTION

COGEMA UP 2 reprocessing plant was built in Cap de La Hague, France in the 1960s and entered service in 1966. While the high-level radioactive liquid waste from this plant had been first concentrated and stored in a tank farm, and vitrified from 1989 onward, the intermediate- and low-level radioactive liquid waste was processed in the STE 2 facility until 1998 and in the STE 3 from then on. STE 2 facility is still occasionally operated for small volumes of liquid waste.

The chemical process used in STE 2, based on the co-precipitation of the fission products and actinides with various chemicals, including calcium carbonate and barium sulfate, and adsorption of cesium on nickel ferrocyanide (PPFeNi), generated sludge waste. The process and the characteristics of the effluent evolved through the operating life of the facility. While the filtered supernatant liquors have been released into the sea, the sludge has been stored in STE 2 silos awaiting retrieval, final conditioning and packaging.

The total volume of sludge stored in the seven STE 2 silos is about 9,000 m^3. It represents a total radioactive content of 70,000 TBq of beta-gamma emitters (mainly ^{137}Cs and ^{90}Sr-Y) and 3,400 TBq of alpha emitters. The sludge dry content, 3300 tons, is about 82 % of precipitated salts and 18% soluble salts, such as sodium nitrate. The sludge has settled during storage in STE 2 silos, so that the sludge concentration may range from 150 to 600 g./l. within a silo.

COGEMA is committed to conditioning the sludge waste stored in the seven STE 2 silos. This task involves the retrieval, characterization, transfer and conditioning of the sludge. The selected conditioning process is encapsulation in bitumen. While bituminization is already in operation at the STE 3 facility, retrieval of this long-stored sludge waste is a new industrial operation at the COGEMA La Hague plant. It had to be designed and planned with great care in order to provide COGEMA with an effective, reliable and cost-effective retrieval system.

A key component of this sludge retrieval program was the Compact Sludge Retrieval system (CSR system) which design, proof-of-principle testing as well as hot testing are described below.

COMPACT SLUDGE RETRIEVAL SYSTEM DESIGN

The sludge evolves from a viscous fluid, when first stored, to a Bingham-type plastic fluid, after having been stored for an extended period of time. Sludge dilution and mixing are therefore required in order to mobilize the sludge into a waste slurry that can be transferred from the silos. Consequently, the following specific functions were required of the Compact Sludge Retrieval system (CSR system):

- Dilution: dilution and mixing action are required in order to limit the pressure drop during transfer and to avoid plugging of transfer hoses and pipes. Dilution should however be optimized in order to minimize secondary waste effluent generation,
- Pumping of the waste slurry.
- Transfer of the waste slurry.

It was soon recognized that the design and implementation of a single mixer capable of stirring the entire sludge content of a silo was not realistic. A decision was made to design, as a component of the CSR system, a mobile mixing and pumping module that could be moved across a silo, could stir and pump sludge from a limited area within a silo, and could retrieve the sludge in the vicinity of that limited area (using, for instance, high-pressure water jets to dislodge lumps of sludge).

The initial design of the mixing and pumping module of the CSR system included a three-blade impeller for mechanical mixing and a submersible membrane pump for retrieval of the waste slurry. Through continuous design improvement, the system has evolved to a submersible helical pump associated with two counter-rotating three-blade impellers. Balancing the torque of the impellers stabilizes the device as it is deployed on cables into a silo through its riser. These cables include the electrical control cables and power cables.

The dimensions of the CSR system mixing and pumping module were limited so as to comply with the dimensional requirements of the STE 2 silos access risers (0.5 m × 0.5 m).

The mixing and pumping module of the CSR system is illustrated in Fig. 1.

Fig. 1 The mixing and pumping module of the CSR system

The CSR system also includes a shielded enclosure designed to be installed on a STE 2 silo access riser. The shielded enclosure contains the cable and hose windings, the rinsing systems, a secondary pump for long-range transfer, a sampling unit and a parking area for the mixing and pumping module (see Fig. 2).

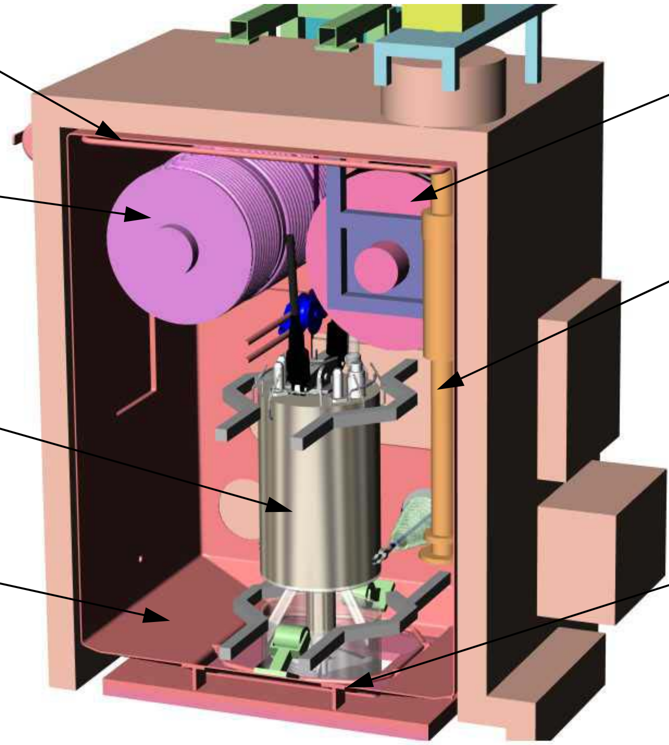

Fig. 2 The CSR system

The CSR system design took into account the limited mechanical strength of the silo top concrete slab by limiting the CSR system total mass.

The CSR system also allows for sampling of the retrieved waste slurry.

The design of the CSR system allows thorough water rinsing of the hoses, pipes and pumps after a slurry transfer. When the submersible mixing and pumping module is parked into the shielded enclosure, it can be water-jet rinsed, together with the cables and hoses. Two rotating nozzles and three fixed washing ramps can also be used to rinse the inside of the shielded enclosure.

COLD TESTING OF MIXING AND PUMPING MODULE

The CSR system mixing and pumping module was built and first tested in a non-radioactive environment at the Beaumont Research Laboratory (HRB). Two series of tests were carried out in a 100-m^3 pool: the first series was devoted to water testing, while the second one was performed using a sludge surrogate.

The main goals of these cold tests were to check the overall efficiency of the mixing and pumping module and to determine its optimized operating parameters. Special attention was given to the amplitude of the module swinging motion which could have been induced by the stirring impellers. Efficient rinsing of the mixing and pumping module and the associated cables, hoses and transfer pipes was also of prime importance.

Water tests were performed to determine and monitor the following parameters:

- tensile stress in the mixing and pumping module supporting cables (which was found to be about 2,300 N.m when the module is out of the water, 1,700 N.m when immersed),
- rotor speed, current intensity and oil temperature of the mixing and pumping module,
- start-up and synchronization of the retrieval and transfer pumps,
- discharge head and flow rate of the retrieval and the transfer pumps.

The pumps performed satisfactorily (a 5-m³/h flow rate is achievable under a 15-bars discharge head) and the mixing performance specifications were met (at 1,000 rpm, the measured impeller discharge rate is of about 1,700 m³/h).

Further tests were carried out after selection of a suitable surrogate material: a low-cost clay that satisfactorily matched the density (from 1.1 at 150 g/l to 1.2 at 300 g/l), and rheological properties (Bingham plastic fluid, with μ_∞ varying from $4.7.10^{-3}$ Pa.s at 150 g/l to $1.92.10^{-2}$ Pa.s at 300 g/l, and τ_y from 2.45 Pa at 150 g/l to 56.9 Pa at 300 g/l) of the STE 2 silo sludge.

These tests with sludge surrogate were conducted on an installation reproducing the isometric paths of the transfer pipes in a STE 2 silo. The feasibility of starting to pump a highly concentrated sludge (> 250 g/l), after an interruption of 24 to 48 hours, without clogging the transfer pipes was thus demonstrated.
The tests also showed that:

- the stirred liquid speed measurement gives an evaluation of sludge homogeneity,
- the discharge head of the pump is directly related to the sludge concentration, as shown in Fig. 3 for a 5-m³/h pumping rate.

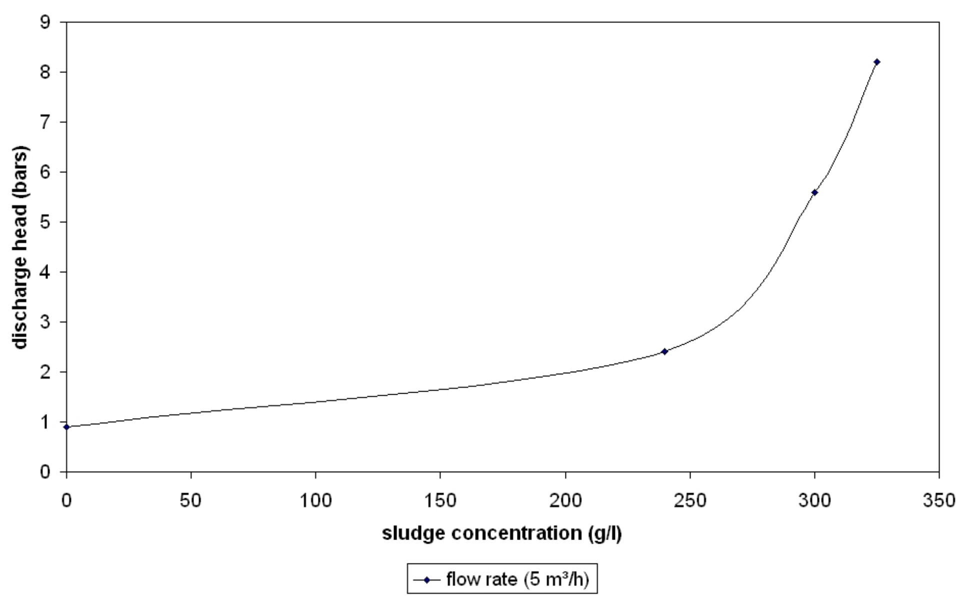

Fig. 3: Discharge head versus sludge concentration

These tests with sludge surrogate led to improvement in the module rinsing equipment and procedure: two watering rings were added to the CSR system to limit the radiation dose when the mixing and pumping module is lifted into the shielded enclosure. One 4-nozzle watering ramp is located under the silo top concrete slab, and another 12-nozzle ramp is located at the middle of the access riser.

Lastly, operating procedures in normal and abnormal conditions, maintenance procedures, rinsing and sampling procedures and procedures for operating personnel training were validated.

HOT TESTS AT COGEMA STE 2 FACILITY

Among the seven STE 2 silos, silo 550-14 was selected for hot tests of the CSR system mainly because of its sludge content composition being representative of that of the other silos.

Sampling of the 550-14 silo content was performed in 1992. The sludge content of silo 550-14 was then characterized as a three-stratification-layer structure according to table 1.

Table I Stratification layers of silo 550-14 sludge content

Concrete	Thickness ~1.15 m
Headspace	Height ~2 m
Supernatant	Height ~0.4 m Volume ~85 m^3
Stratification layer # 1	Height ~2 m Concentration range ~200 to 300 g/l
Stratification layer # 2	Height ~3.5 m Concentration range ~300 to 400 g/l
Stratification layer # 3	Height ~3.5 m Concentration range ~500 g/l

The total volume of settled sludge in silo 550-14 is of about 2000 m^3 and the total dry residue mass amounts to approximately 880 tons.

Hot tests of the CSR system in silo 550-14 started in 2002. The mixing and pumping module was first lowered down to stratification layer # 1 in September 2002, then down to stratification layers # 2 and 3 in October and November 2002, respectively.

The amount of sludge transferred from each of the three stratification layers in silo 550-14, together with the corresponding operating time, are given in Table II.

Table II Transferred slurry and secondary liquid waste generated during the hot tests

Stratification layer	**# 1**	**# 2**	**# 3**
Transferred slurry			
volume (m^3)	21	53.9	34.2
dry residue content (g/l)	~ 25	43	69
Operating time			
sludge mixing without transfer (h)	57	53	56
transfer (h)	4.5	14	32
Dilution			
dilution water (m^3/m^3 of sludge)	/	0.015	0.75
Rinsing			
rinsing of transfer pipes (m^3/m^3 of transferred slurry)	0.16	0.06	0.3
filter unplugging (m^3/m^3 of transferred slurry)	/	0.055	1.7

The hot tests showed that the amount of water required to dilute the waste slurry down to 80 g/l before transfer ranged from 15 to 750 liters per cubic meter of transferred slurry, depending upon which stratification layer the sludge was retrieved from (see Table 1).

The amount of water required to rinse the transfer pipes was found to range from 60 to 300 liters per cubic meter of transferred slurry, depending on the volume of each batch.

The amount of water required to unclog the transfer filter ranged between 55 and 1,700 liters per cubic meter of transferred slurry. This volume is proportional to the frequency of filter unclogging operations.

These hot tests confirmed that the CSR system performed the required functions: mixing, pumping, sampling and transfer. The retrieval pump performed satisfactorily up to dry residue concentrations of 300 g/l. Furthermore, the retrieval and transfer pumps could be satisfactorily synchronized. It was also found that slurry transfer could be performed with dry residue concentrations up to 170 g/l.

It was also observed that the stirring and pumping module mobilizes sludge waste in a limited neighborhood of its suction head:

- in stratification layer # 1, sludge was disturbed within 3 m of the stirring and pumping module,
- in stratification layer # 3, sludge was disturbed within 1 m of the module.

Other hot tests were performed to gain further knowledge of the transfer filter clogging mechanism and of the correlation between the dose rate at the transfer filter and at the transfer pipes and the dry residue concentration in the transferred slurry.

CONCLUSION

After initial design, the Compact Sludge Retrieval system underwent testing performance validation at COGEMA Beaumont Research Laboratory.

The lessons learned from these cold tests were applied to the final design of the CSR system which was subsequently deployed in a STE 2 silo, silo 550-14, in 2002.

Sludge waste retrieval operations conducted in silo 550-14 were considered hot tests for the CSR system.

These hot tests proved successful and are now followed industrial implementation at the STE 2 facility and at the Tchernobyl Liquid Radwaste Treatment Plant (LRTP), Ukraine.