Final Treatment Center Project for Liquid and Wet Radioactive Waste in Slovakia

K. Kravarik, M. Stubna, A. Pekar, T. Krajc, M. Zatkulak, Z. Holicka
VUJE, Inc.
Okruzna 5, 918 64 Trnava, Slovak Republic

M. Slezak
SE - VYZ
919 31 Jaslovske Bohunice, Slovak Republic

ABSTRACT

The Final Treatment Center (FTC) for Mochovce nuclear power plant (NPP) is designed for treatment and final conditioning of radioactive liquid and wet waste produced from plant operation. Mochovce NNP uses a Russian VVER-440 type reactor. Treated wastes comprise radioactive concentrates, spent resin and sludge. VUJE Inc. as an experienced company in field of treatment of radioactive waste in Slovakia has been chosen as main contractor for technological part of FTC. This paper describes the capacity, flow chart, overall waste flow and parameters of the main components in the FTC.

The initial project was submitted for approval to the Slovak Electric plc. in 2003. The design and manufacture of main components were performed in 2004 and 2005. FTC construction work started early in 2004. Initial non-radioactive testing of the system is planned for summer 2006 and then radioactive tests are to be followed. A one-year trial operation of facility is planned for completion in 2007.

SE - VYZ will be operates the FTC during trial operation and after its completion. SE - VYZ is subsidiary company of Slovak Electric plc. and it is responsible for treatment with radioactive waste and spent fuel in the Slovak republic. SE - VYZ has, besides of other significant experience with operation of Jaslovske Bohunice Treatment Centre.

The overall capacity of the FTC is 870 m^3/year of concentrates and 40 m^3/year of spent resin and sludge. Bituminization and cementation were provided as main technologies for treatment of these wastes. Treatment of concentrate is performed by bituminization. Concentrate and bitumen are metered into a thin film evaporator with rotating wiping blades. Surplus water is evaporated and concentrate salts are embedded in bitumen. Bitumen product is discharged into 200 l steel drums. Spent resin and sludge are decanted, dried and mixed with bitumen. These mixtures are also discharged into 200 l steel drums. Drums are moved along bituminization line on a roller conveyor. After the drums cool, they are capped and removed from the conveyor and placed in a storage hall.

Drums with bitumen product are loaded into Fiber Reinforced Concrete containers (FRC) and grouted with cement. Cement grout is prepared from mixture of cement, additive and radioactive

concentrates. By formulating the cement grout with evaporator concentrates the maximum radioactivity is fixed in cement matrix and volume of final waste product is minimized. A batch mixer with rotating blades is used produce the cement grout. FRCs loaded with bitumen drums are placed on roller conveyor and moved along the cementation line. Grouted FRCs are stored in the expedition hall for 28 days of curing and then transported to final disposal.

After placed in operation the FTC provides treatment for all liquid and wet LLW produced from the operation of the Mochovce NPP. The final product of the FTC is a FRC loaded with 7 drums of waste fixed in bitumen and the space between the drums is grouted with cement. This container meets all limits for final disposal in the National Radioactive Waste Repository at Mochovce.

INTRODUCTION

Currently, there are two units in operation at Mochovce NPP (1st and 2nd). The other two units are under temporary halt in construction (3rd and 4th). The reactors are of the Russian VVER-440 design. Mochovce NPP did not have a treatment center for final conditioning of LLW produced from plant operation. Operating experience at Jaslovske Bohunice NPP indicates that the overall production of four reactors should be 600 m^3 of concentrate and 4-10 m^3 of spent resins per year. For the future operation of Mochovce it is essential to build the Final Treatment Center (FTC) for radioactive liquid and wet waste treatment.

The Nuclear Regulatory Authority of the Slovak Republic, after discussion with other relevant bodies, decides to fix LLW wastes mainly in cement or bitumen matrix using 200 l steel drums. Fiber reinforced concrete containers (FRC) are used for disposal of these products in the National Radioactive Waste Repository at Mochovce, which is already in operation. The design of FTC is in accordance with the requirements of the Regulatory Authority. Concentrates, spent resin and sludge are processed by bituminization. Bitumen product is discharged into 200 l drums. Drums are loaded into FRC and grouted with cement. After a curing period, FRC are transported to National Radioactive Waste Repository at Mochovce for final disposal.

TREATED WASTE CHARACTERIZATION

Controlled and uncontrolled leakages waste water from primary circuit is collected by system of special sewage of Mochovce NPP in storage tanks. Waste water from technological processes (e. g. regeneration of resin filters at primary circuit purifying station) are collected also in storage tanks. These wastes are treated by evaporation at auxiliary building (AB) and concentrates are stored in storage tanks. The predicted overall production of concentrates from four reactors at the Mochovce NPP is 600 m^3 per year. The storage capacity for concentrates is 4 x 550 m^3 and for spent resin 2 x 460 m^3 at Mochovce NPP. The typical physical and chemical properties of concentrates are as follows:

pH:	12.8-13.3
density:	1.14-1.16 g/cm^3

content of salt:	155-190 g/l
content of inslube particles	2-6 g/l
content of borate acid:	103-115 g/l
content of natrium:	36-41 g/l
content of nitrates:	4-13 g/l
content of oxalates:	0.5-1.0 g/l
content of chlorides:	0.2-0.3 g/l
^{3}H	max 2 E5 Bq/l
^{60}Co	max 4 E3 Bq/l
^{134}Cs	max 4 E4 Bq/l
^{137}Cs	max 2 E5 Bq/l

Spent resin and sludge arise from primary circuit purification station and supporting systems (e. g. cooling and cleaning of spent fuel pool). Spent resin are exchange by new one after several regeneration cycles. Spent resin are stored in storage tanks. Their dominant contaminants are ^{60}Co with max. activity 2 E7 Bq/l and ^{37}Cs with max. activity 2 E9 Bq/l.

These properties are similar to the concentrates and spent resin produced at NPP Jaslovske Bohunice.

TECHNOLOGY DESCRIPTION

The FTC will process all liquid and wet LLW produced at Mochovce NPP. Bituminization and cementation are used as main technologies for treatment of waste. The FTC is built next to the auxiliary building (AB), where the wastes are stored and produced. The FTC building has dimension 60 m x 40 m and has 6 floors (one of them underground). Wastes are pumped into the FTC receiving tanks from the AB. Supporting utilities such as compressed air, steam, decontamination solutions etc. are supplied from the AB also.

Concentrates are processed by bituminization. Concentrates and bitumen are metered into a thin film evaporator according prescribed procedures. Surplus water is evaporated and concentrated salts are mixed with bitumen. Bitumen product is discharged into 200 l steel drums. Spent resin and sludge are decanted, dried and mixed with bitumen. Bitumen product is also discharged into 200 l steel drums. Drums are moved along the bituminization line on a roller conveyor. After the drums cool, they are capped and removed from the conveyor and placed into storage.

The final product of FTC is a Fiber Reinforced Concrete container (FRC). Seven drums with bitumen product are loaded into a FRC and the space between the drums is grouted with cement. Cement grout is prepared from mixture of cement, additive and evaporator concentrates according prescribed procedures. Spent resin or sludge can be used instead of concentrates for cement grout preparation.

Bituminization

The simplified flow chart of concentrate, spent resin and sludge bituminization is shown in Figure 1.

Bituminization of concentrates

Concentrates are pumped into receiving tanks of the FTC (1a, 1b) from the Auxiliary Building (AB). The tanks are located on the underground floor of the FTC and their capacity is 2 x 8.5 m^3. They are provided with mixers and heated by steam at a temperature 40 °C to prevent crystallization of salts. They are also used for pH adjustment before the concentrates are treated on bituminization line. Concentrates are pumped into the concentrates feed tank (3). The tank is provided with a mixer and a duplicator. The concentrates temperature is kept at 80 °C. The level of concentrates in the tank is automatically controlled. Concentrates and bitumen (27) are metered into the evaporator (4) and the concentrate salts are embedded in bitumen. The evaporator is designed as a thin film evaporator with rotating wiping blades. Its working temperature is 180 °C and its output is 175 to 200 kg/hour of evaporated water. Concentrates and bitumen are metered to the top of the evaporator, wiped by blades, concentrated and homogenized. The feed rate of concentrates is 220 to 240 kg/hour and bitumen is 70 to 80 kg/hour. Bitumen is preheated to a temperature of 120 to 130 °C in its feed tank prior to routing to the evaporator.

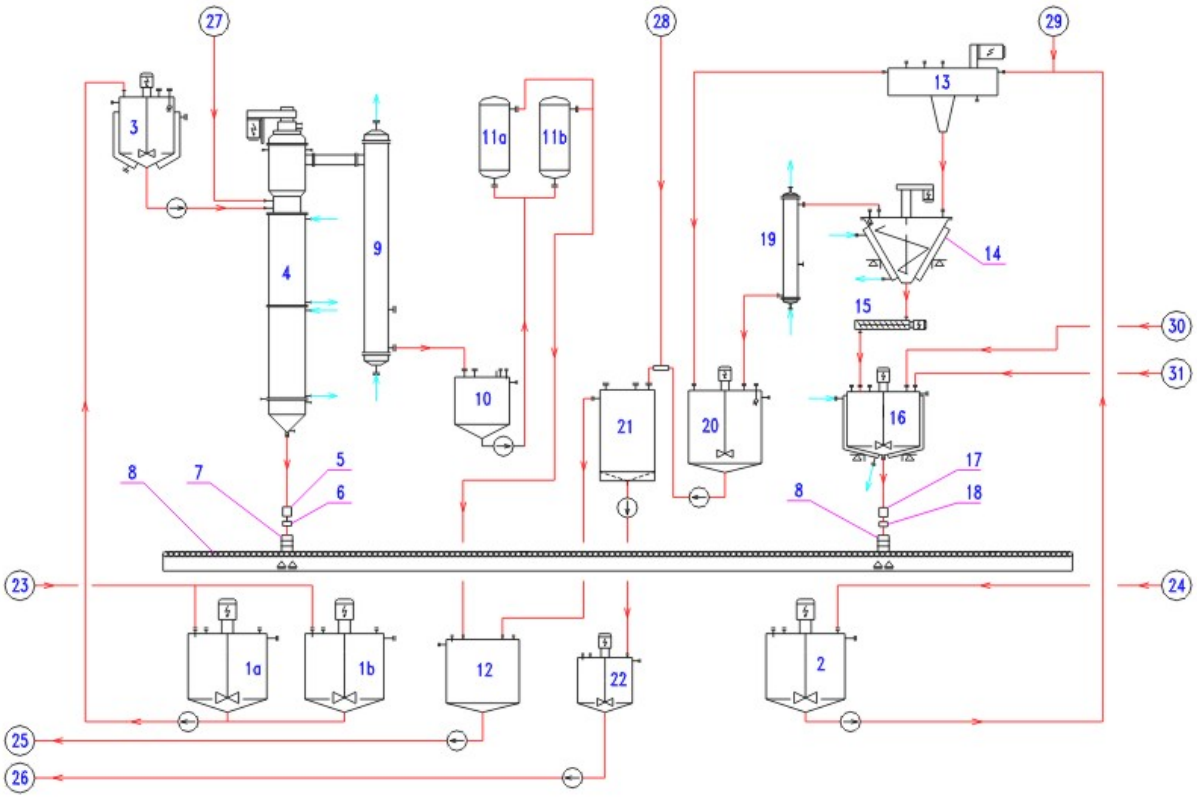

Fig. No. 1 Simplified flow chart of concentrates, spent resin and sludge bituminization.

Bitumen product is discharged from the bottom nozzle of the evaporator into 200 l steel drum (7) by charging equipment (5). Drums are placed on the roller conveyor, which moves them under the bituminization line. The level of bitumen product in the drum and drum weight are measured at the fill station. While filling the drum a sample of bitumen product is taken by a sampling unit (6). When the drum is full, charging is stopped and the roller conveyor is moved one position forward, (i.e. the width of one drum). An empty drum is positioned under charging equipment and charging of bitumen product continues. The roller conveyor is long enough that filled drums can cool off before they reach the capping station. When the drums are automatically capped the surface dose rate is measured and they are marked with a bar code. At the end of the roller conveyor the drum is taken by crane and placed into the storage hall. The storage hall capacity is 216 drums.

Vapor from the evaporator is routed into a condenser (9). The condenser is vertical tube heat exchanger, which uses service water for the cooling medium. The flow rate of cooling water is 5 to 12 m^3/hour. Condensate is collected in a distillate tank (10). The condensate is pumped into the bottom of a treatment vessel (11a, 11b) in periodic interval (according the level of condensate in tank) to be cleaned. The vessels are filed with activated carbon and one of them serves as a reserve. The cleaned condensate flows by gravity to the storage tanks (12), which are located in the basement. The cleaned condensate can be used for flushing components in the FTC or pumped back to the AB for future reuse.

Bituminization of spent resin and sludge

Mixtures of spent resin and sludge are pumped into a receiving tank of FTC (2) from the AB. The spent resin and sludge receiving tank is located in the basement of the FTC and its capacity is 8.5 m^3. It is provided with a mixer. Mixtures of spent resin and sludge are diluted in receiving tank that the dry residue content of the suspension ranges from 5 to 7 %.

Spent resin and sludge are treated by bituminization in batch. Spent resin and sludge suspended by sluice water is pumped into a decanter (13). There is an in-line mixer (29) on the inlet to the decanter, which is used for adding flocculation Additive I to the suspension. Additive I is added in case of treatment mixture of spent resin and sludge. The flocculation Additive I is prepared in a flocculation unit with capacity 250 to 300 dm^3. The feed rate of flocculation additives is 25 to 30 dm^3/hour.

Spent resin and sludge gravity flows from the decanter into the spent resins and sludge dryer (14). The solids content of dryer residue is 40 % in outlet scream from decanter. The drier has volume 400 dm^3 and is a cone shaped vessel placed on tensometers. It is provided with mixer (wiping blades) and heated by steam. When the drier is filled with spent resin and sludge (it is controlled by measurement of the drier weight), waste addition to the decanter is stopped and the decanter is automatically flushed and switched off. The drying process is control by measurement of decreasing drier weight. Drying time for one batch is 12 to 15 hours. The residual water content of dried waste is less than 5 %.

Solidification of spent resin and sludge in bitumen follows the drying cycle and is performed in a batch mixer (16). The batch mixer has rotating blades, is heated with steam and mounted on

tensometers. The required amount of bitumen (30) is feed into mixer to yield a product that is 60 % bitumen by weight. Bitumen is preheated to a temperature of 120 to 130 °C in its feed tank. After bitumen is feed into the mixer a small amount of Additive III (31) is added (20 to 30 kg per batch) to increases viscosity of the product. Dried spent resin and sludge are gradually metered into the mixer and homogenize with the bitumen.

The mixture is discharged from the mixer into 200 l steel drums similar to what was described for the solidification of concentrates. Two and half of drums are filled from one batch of dried spent resin and sludge. Overall cycle duration for preparation of one batch is approximately 20 hours.

During the drying, vapor from the dryer is routed to a condenser (19). The condenser is vertical tube heat exchanger, which uses service water as cooling medium. The flow rate of cooling water is 0.8 to 1.2 m^3/hour. Condensate is collected in a distillate tank (20). Decanted water from decanter is colleted in this tank also. The tank is provided with a mixer. Tank content is periodically routed to EVH filter (21). There is a flocculator (in-line mixer) on the inlet to the filter, which is used for adding flocculation Additive II (28) to the suspension. Filtrate is collected in the storage tank of treated condensate (12). Sludge from the filter is collected in the sludge storage tank (22), which is located in the basement. Drums with bitumen product are stored in the storage hall.

Concentrates, spent resin and sludge bituminization represents high fire hazard, because bitumen is flammable material. There was no accident related to flammability of bitumen or bitumen product at Jaslovske Bohunice bituminization plant since it has been put into operation in 1994. The bitumen ignition temperature is 230°C. The temperature of bitumen product poured into drums is approx. 165°C. The FTC building is divided into several sections according fire risk with necessary fire fighting equipment and fire escape corridors. The filling stations of drums with bitumen products are furthermore equipped with automatic extinguishing system.

Cement grout preparation

Drums with bitumen product are loaded into a Fiber Reinforced Concrete Container (FRC) in the storage hall. Even loaded with seven drums surface dose rate on a FRC is less than 2 mSv. Drums are handled remotely. When the FRC is loaded with drums the lid is installed and the container is ready for grouting. There are two holes in the FRC lid, one is used for adding cement grout and another one to vent and observe the grout level.

The simplified flow chart of FRC grouting is shown in Fig. 2. Cement grout is prepared from mixture of cement, lime hydrate and radioactive concentrates according to a prescription. The prescription is determined on the results of laboratory analyses of concentrate properties. Spent resin or sludge can be used instead of concentrate.

Cement and zeolite are stored in bins (12a respectively 12b). The bins are filled from tanker trucks pneumatically. Lime hydrate is supplied from bags by a screw feeder (8) to a storage bin (9). Cement grout is prepared using concentrates from the recirculation evaporator (3). This increases the amount of radioactivity embedded in FRCs to efficiently use disposal capacity at National Radioactive Waste Repository at Mochovce.

Concentrates with 200 g of salt/l are pumped from storage tanks (1a or 1b - same tanks that are used for bituminization line) into the recirculation evaporator (3). A tube preheater (2) preheats concentrates to a temperature 90 °C at the inlet to the evaporator. The recirculation evaporator is used to reduce scaling on heat exchange surfaces in the evaporator. Concentrate is feed into the bottom part of the evaporator, flows through tubes and is heated by steam. Vapor and liquid are separated at the top of the evaporator. The recirculation tube, which connected the top and the bottom part of the evaporator, provides natural circulation of concentrates. The output of evaporator is 190 kg/hour of evaporated water. The salt concentration in output stream is up to 400 g/l. The evaporator works continuously. Concentrates are taken from the cyclone separator at the top part of the evaporator and collected in a concentrates storage tank (5), which is placed below the evaporator on the level +11.0 m. The tank is provided with mixer and is heated by steam to keep the temperature of concentrates above 40 °C. Vapor is routed to a tube condenser (4) and condensate is collected in the condensate storage tank (21), same one used for bituminization line. Concentrates are pumped from storage tank (5) to a concentrates feed tank of cementation line (6). The tank is provided with mixer and it can be heated or cooled. The temperature of concentrates is kept at 40 °C.

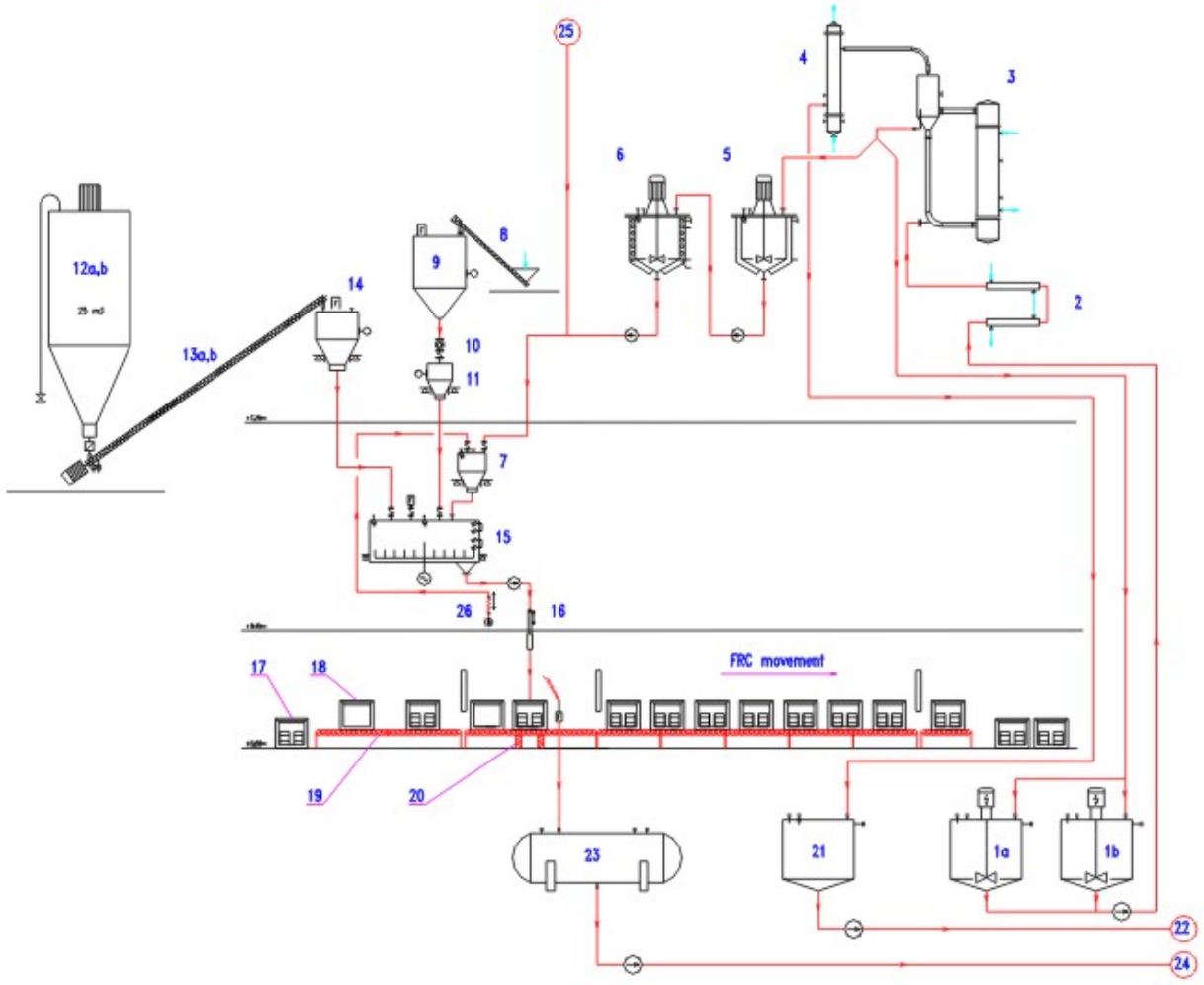

Fig. No. 2 Simplified flow chart of FRC cementation.

Cement grout is prepared in 500 l batch in a cement grout mixer (15). The unit is drum mixer with rotating blades. Cement is added via a cement weighing unit (14) from the cement storage bin (12a) by the cement screw feeder (13a). After that, zeolite is added from the zeolite storage bin to the same weighing unit by the zeolite screw feeder (13b). A defined amount of lime hydrate is added from the lime hydrate storage bin (9) to a lime hydrate weighing unit (11) by a turnstile feeder (10). The prescribed amount of concentrates is pumped from the concentrates feed tank (6) into a concentrates weighing unit (7).

When all components are weighed they are gradually feed from the weighing units to the cement grout mixer (15). At first, the concentrates are mixed with lime hydrate for 20 minutes. After that, the cement and zeolite are added. The overall time to add and mix all cement grout components is 45 minutes.

A FRC loaded with bitumen product drums (17) is put on a roller conveyor (19), which moves it to a filling position under the cement grout mixer. A filling tube (16) is lowered into the fill port of the FRC lid. Cement grout is discharged into FRC by a cement grout pump. Three batches of cement grout (500 l) are needed to fill a FRC. An ultrasonic probe monitors the level of cement grout in container. While filling a sample of cement grout is taken. After each grout batch is loaded, the FRC is lifted and vibrated on a vibration plate (20). Vibration is used to improve the cement grout flow and enable air to escape so that voids in the grout are prevented. The cement grout mixer, the cement pump and the filling tube are rinsed after each run. Demineralized water or treated condensate is used for rinsing. Rinse water is collected in a FRC assigned for this purpose and it is regularly decanted by a pump (26) and used to prepare cement grout. Decontamination solutions are collected in a waste water storage tank (23).

When the FRC is full, the roller conveyor is moved one position forward and another container with bitumen drums is moved under the filling tube. There are seven positions for grouted FRCs on the roller conveyer, which enable the cement grout to set. At the end of the roller conveyor the FRC is taken by crane, the lid is sealed and container is placed to the expedition hall. Containers are stored in the hall for a curing period and then they are transported to the National Radioactive Waste Repository at Mochovce for final disposal.

FTC CAPACITY

FTC will operate on a campaign schedule. It is designed so that five campaigns of bituminization of concentrates and one campaign of bituminization of resin and sludge will be conducted per year. During the bituminization campaigns a sufficient amount of drums with bitumen product will be produced. Cementation campaign will follow after each bituminization campaign. Following amount of wastes, drums and FRC will be processed:

Concentrates bituminization campaigns:

Concentrates:	100 m^3/campaign	500 m^3/year
Drums:	210 per campaign	1050 per year

Cementation campaigns after concentrates bituminization campaigns:

Concentrates:	64.4 m^3/campaign	322 m^3/year
Concentrated concentrate:	62.2 m^3/campaign	161 m^3/year
Drums:	210 per campaign	1050 per year
FRC:	30 per campaign	150 per year

Bituminization of spent resin and sludge:

Spent resin and sludge:	40 m^3/campaign	40 m^3/year
Drums:	155 per campaign	155 per year

Cementation campaigns after spent resin and sludge bituminization campaigns:

Concentrates:	47.5 m^3/campaign	47.5 m^3/year
Concentrated concentrate:	24 m3/campaign	24 m^3/year
Drums:	155 per campaign	155 per year
FRC:	22 per campaign	22 per year

The overall capacity of FTC is:

- 870 m^3/year of concentrates,
- 40 m^3/year spent resin and sludge.

This represents:

- 1 205 drums with bitumen product,
- 172 Fiber Reinforced Concrete Container.

Containers will be transported to the National Radioactive Waste Repository at Mochovce for final disposal.

CONCLUSION

FTC design respects principles of waste treatment in the Slovak Republic. The final product, FRC with grouted drums of bitumen solidified waste, will be disposed at National Radioactive Waste Repository at Mochovce.

VUJE as an experienced company in the field of bituminization and cementation was chosen as a general contractor for design and procurement of Final Treatment Center for Liquid and wet LLW at Mochovce. Experience with treatment of similar waste at Jaslovské Bohunice NPP was utilized. The systems and components were tested and demonstrated by treatment of radioactive waste.

At the time of this paper submittal, the FTC building and installation of components was complete. Programs for non radioactive and radioactive testing of FTC are elaborated and approved by Slovak Electric plc. Facility testing (non radioactive and radioactive) will be performed in 2006. FTC will be put in trial operation at the beginning of 2007.

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