Radioactive Spent Resins Conditioning by the Hot Supercompaction Process at Tihange NPP - 8018

Baudouin Centner and Serge Vanderperre
Nuclear Department, Tractebel Engineering
Avenue Ariane 7 – B-1200 Brussels - Belgium

ABSTRACT

Spent ion-exchange media are considered to be problematic waste that, in many cases, requires special approaches and precautions during its immobilization to meet the acceptance criteria for disposal. The waste acceptance criteria define, among others, the quality of waste forms for disposal, and therefore will sometimes define appropriate treatment options.

The selection of treatment options for spent ion-exchange materials must consider their physical and chemical characteristics. Basically, the main methods for the treatment of spent organic ion-exchange materials, following to pre-treatment methods are :

- Direct immobilization, producing a stable end product by using cement, bitumen, polymer or high integrity containers;
- The destruction of the organic compounds by using thermochemical processes or oxidation to produce an inorganic intermediate product that may or may not be further conditioned for storage and/or disposal;
- The complete removal of the resin inner structural water by a thermal process, followed by a supercompaction of the hot dried resins.

At Tihange Nuclear Power Plant, spent ion-exchange resins were conditioned by embedding in a polymer matrix with a mobile processing installation. For safety and cost reasons, Electrabel, the Belgian Utility, decided to investigate by which process the former one should be replaced. To carry out this mission, Electrabel entrusted Tractebel Engineering with the selection of the most suitable process available on the international market. After a thorough technical economical analysis, Tractebel Engineering selected the Resin Hot Supercompaction Process to be installed at Tihange Nuclear Power Plant.

The Resin Hot Supercompaction Process is used to make water free dense homogeneous organic blocks from a wide range of particulate waste. In this process, spent resins are first dewatered and dried to remove the inner structural water content. The drying takes place in a drying vessel that holds the contents of two 200 l drums. In the oil heated drying and mixing unit, the resins are heated to the necessary process temperature for the structural inner water removal and for the hot pressing step. They are then collected into special metal drums, which are automatically provided with a lid and immediately transferred to a high force compactor. After high force compaction, the pellets are transferred to a measuring unit, where the dose rate, height and weight are automatically measured and recorded. A Volume Reduction Factor (VRF) of approximately up to four (depending on the type of resins) is achievable using hot compaction techniques.

This paper describes the application of the Resin Hot Supercompaction Process at Tihange Nuclear Power Plant.

INTRODUCTION

Ion exchange is one of the most common and effective treatment methods for liquid radioactive waste. Spent ion exchange media are considered to be problematic waste that, in many cases, requires special approaches and precautions during its immobilization to meet the acceptance criteria for disposal.

With the evolution of performance-based disposal facility acceptance criteria, it is now required that spent ion exchange materials meet specific quality requirements prior to disposal. Where final disposal facilities exist, waste acceptance criteria define, among others, the quality of waste forms for disposal, and therefore will sometimes define appropriate treatment options; for example, disposal facilities normally define acceptable levels of free liquids and requirements for waste form stability as part of their waste acceptance criteria.

The selection of treatment options for spent ion exchange materials must consider their physical, chemical and radiological characteristics. Basically, two of the main methods for the treatment of spent organic ion exchange materials, following pretreatment methods like dewatering, grinding, foaming or decontamination by activity stripping are [1] :

- Direct immobilization, producing a stable end product by using cement, bitumen, polymer or high integrity containers;
- The complete removal of the resin inner structural water by a thermal process followed by the supercompaction of the hot dried resins.

In its first part, this paper will describe the principle of the process of the Resin Hot High Force Compaction implemented in a German NPP. In its second part, the paper will introduce a new application of the Resin Hot High Force Compaction Process to Tihange NPP in Belgium.

PROCESS DESCRIPTION – GERMAN NPP EXPERIENCE

At the German plant, the spent resins are first dewatered by a centrifuge (separator and decanter) system and filled in 200 l drums. The 200 l drums will be transferred to a thermal-oil heated drying vessel that holds the contents of two 200 l drums (Fig. 1.) and the resins will be removed by a special device from the drum.

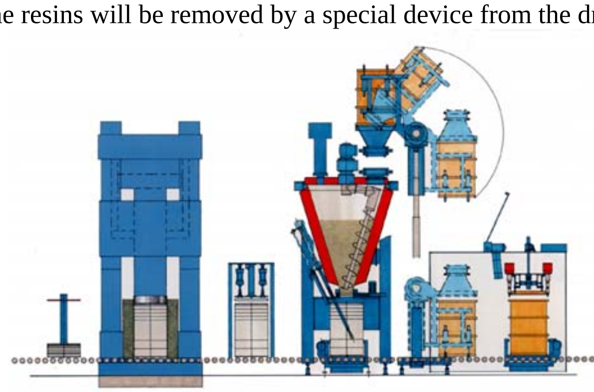

Fig. 1. : Principle of the HPA - Resin Hot High Force Compaction Process at the German NPP (From right to left : Resin drum lifting device – dryer – automatic copping device – supercompactor – resin pellet)

This vessel can also be used for mixing bead and powder resins. In the drying and mixing unit, the resins are heated to the necessary process temperature. After meeting the drying criteria, the resins are released into special metal press drums, on which a lid is automatically placed. After these operations, the drums are immediately transferred to a high force compactor. After high force compaction, the pellets are transferred to a measuring unit, where the dose rate, height and weight are automatically measured and recorded.

The key benefits of the process are :

- a high Volume Reduction Factor (VRF, typically 4:1) : in this case the VRF =

$$\frac{\text{height of the 200 l resin drum before compaction}}{\text{height of the pellet after drum compaction}}$$

- an end product in the form of a homogeneous organic pellet free of water.

EXPERIENCE FROM COMMERCIAL OPERATION AT THE GERMAN NPP

Selection of the Conditioning Process

Volume reduction was set as the main criterion in an environment with no final disposal options and a limited interim storage capacity. After successful performance of two trial campaigns with mobile equipment in 1990 and 1991, the lessons learnt had been fed back in the design of the stationary equipment that has been started up in 1995.

Volume of Spent Ion Exchange Resins at the German NPP

The German NPP site is provided with two units : one Boiling Water Reactor (BWR) with a power of 926 MW_{el} and one Pressurized Water Reactor (PWR) with a power of 1.458 MW_{el}.

The respective systems of the BWR are operated mostly with powdered resins, but in the PWR the use of bead resins is common. The annual volume of resins at the German plant consists of approximately 23 m^3 powdered resins and approximately 3 m^3 bead resins.

Treatment of Spent Ion Exchange Resins

- **Dewatering and Filling of the Spent Ion Exchange Resins**

The Spent Ion Exchange Resins are pumped in tanks for interim storage. Prior to the filling of the 200 l drums, the bead and powdered resins are dewatered by a stationary centrifuge system (Decanter/ Separator).

- **Conditioning Operations**

The equipment installed in the waste conditioning building, especially the High Force Compactor, are operated beside their function in the Resin Hot High Force Compaction Process also for the treatment of mixed waste, evaporator concentrates as well as sludges. In this respect, the treatment of each waste stream is performed in campaigns in one shift operations. For the operation of the waste conditioning processes, two operators are needed.

Additionally one operator is needed for the necessary crane activities during transport from and back to the interim drum storage area as well as the overpack filling with the resulting pellets.

The throughput of the conditioning system for the Resin Hot High Force Compaction Process is mainly determined by the drying time, which depends closely on the contents of moisture in the resins. For that reason, the resins will be dewatered upstream first. After dewatering, the residual internal structural water inventory may be as high as 50-60% of the bead resin total weight.

As mentioned before, the drying of bead resins is done only in combination with powdered resins. Consequently, the volume of the to be dried mixed resins is bigger than the volume of powdered resins. Subsequently, the typical duration of one drying cycle varies from 1.6 h (powdered resins only) to 2.3 h (mixture from bead- and powdered resins).

The average height of the pellets varies from 18.2 cm (powdered resins) to 22.4 cm (mixed resins). Consequently 3 to 4 pellets can be placed in a 200 l drum. The operator can select from various pellets the best combination to achieve the best filling grade. The average filling grade achieved during commercial operation is 3.9 pellets per drum.

- **Data Collection and Waste Tracking System**

All relevant data of the product are measured during the conditioning process, are combined with the respective waste packages via barcode identification and are transferred to the plants waste tracking system and database (BAV).

Duration of a campaign – Process Throughput Rate

The amount of powdered resins (23m³) and bead resins (3m³) corresponds to 234 drums of powdered resins and 32 drums of bead resins to be processed per year.

Based on the above throughput data (12 respectively 15 drums per week), the total duration of an annual campaign can be calculated to be approximately 19 weeks.

The conditioning process generates 266 pellets (1 drum of dewatered resins = 1 pellet) per year, that will be placed in approximately 68 drums. The volume of a drum being 0.27 m³, the resulting volume for interim storage is 18.36 m³. Finally the overpack drums containing the pellets are interim stored on site.

The dried hot resin supercompaction unit is remotely operated by a PLC (Program Logic Controller) system. There is thus no operator radiological exposure resulting from the unit operation.

Evaluation of the Process

The stationary facility at the German plant has produced more than 3 800 pellets since 1995 [2].

The pellets generated in the stationary facility have been packed in 200 l drums. Since December 31st, 2006, in total 975 x 200 l drums have been packed. Some 328 of them have been delivered to the final repository site in Morsleben and the rest is located in the interim drum stores of the plant.

The advantage of the process is that products suitable for final disposal will be generated and, at the same time, an important volume reduction for interim storage will be achieved. Moreover, in respect of the future final disposal options, decisions on the final waste packages according to future requirements are very flexible, because the pellets can be very easily retrieved from the 200 l drums or the 200 l drums can be placed in final disposal packages.

NEW APPLICATION OF THE RESIN HOT HIGH FORCE COMPACTION PROCESS TO THE NUCLEAR POWER PLANT TIHANGE IN BELGIUM

Spent Resin Conditioning Process Selection at Tihange NPP

- **Tihange NPP Approach**

The Tihange NPP (3 x 1000 MWe PWRs) spent resin production amounts to some 10-12 m^3/year. Until 2005, these resins were immobilised in an organic matrix (styrol, epoxy based materials) by use of a mobile unit provided by external service supply companies. The resins are immobilized in the ONDRAF/NIRAS[(1)] licensed 400 liter drums, on the basis of one campaign (30-36 m^3) every three years. The process global VRF was found to lay in the range

0.5 - 0.6 (VRF = $\frac{\text{Total volume of dewatered resins to be processed}}{\text{Total volume of the produced 400 liter drums}}$).

Due to concerns linked to the high cost of the process, Tihange NPP requested in 2005, from Tractebel Engineering, a complete survey and reassessment of the currently available and industrially proven spent resin conditioning processes with, as final aim, the recommendation of the best suited process taking into account the internal/external constraints prevailing at the plant.

Each surveyed process was assessed in accordance with the 6 following criteria :

- Overall cost including, as appropriate : investment, consumables, operation/maintenance, secondary waste management, process qualification, management of the conditioned waste packages (transportation, interim storage, final disposal), dismantling (in case of a new fixed installation);
- Autonomy (fixed installation) versus dependence (mobile external installation);
- Manpower requested qualification for the process implementation;
- Qualification of the process, i.e. compliance of the end product with the ONDRAF/NIRAS Waste Acceptance Criteria (WAC);

(1) ONDRAF/NIRAS : Belgian State owned company in charge of the collection, the conditioning and the final disposal of the radioactive waste produced in Belgium.

- Nuclear and industrial safety (fire risk, presence of carcinogenic and/or mutagenic components in the conditioning process);
- Industrial References.

For each process, each criterion was quoted from 1 (lowest ranked process) to 6 (best ranked process). A weighing factor was then attributed to each criterion, enabling to end up with an optimised proposal. Sensitivity analysis, including variations of the weighing factor numerical values, enabled to test the robustness of the proposal against uncertainties.

- **Conclusions**

The implementation of this multi-criteria analysis enabled to recommend the installation of a fixed dried resin hot supercompaction unit, i.e. the by far best ranked process, under the constraints prevailing at Tihange NPP.

Process Modifications

The most critical issue for a successful process configuration is the duroplastic behavior of the resins, in particular of the bead resins. This behavior prevents the resins from building a homogeneous, solid block and, in the worst case, leads to bursting the metal surface of the pellet ("Spring back effect" – see Fig. 2.). In this respect, the presence of powdered resins occupying the gaps between the bead resin and of the thermoplastic AF2 material, acting as glue, optimizes the process conditions in the case of Philippsburg NPP application. Therefore in order to adapt the Resin Hot High Force Compaction Process to a PWR plant with bead resin arising only, various intensive laboratory and full scale test trials had to be performed to adjust the process parameters to handle this effect.

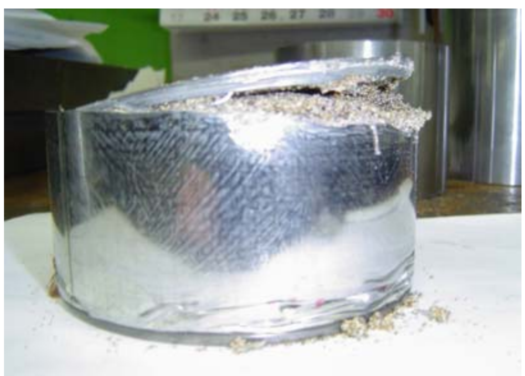

Fig. 2. "Spring Back Effect" when bead resins only are supercompacted

The test operations mainly focused on the selection of the most suitable type of additive material and the minimization of the volume needed for running the process. In combination with the adjustment of the equipment parameters of the drying and compaction unit, finally an additive (polypropylene in powder form) has been identified that assures the required properties of the resulting waste product with a minimum volume needed.

Equipment Modifications

The main components used in the application of the Resin Hot High Force Compaction Process for Tihange NPP are a 500 liter conical drying unit as well as a 2 000 t supercompactor like in the German plant. Nevertheless, taking the specific requirements into account, the following modifications have been introduced (Fig. 3. and 4.):

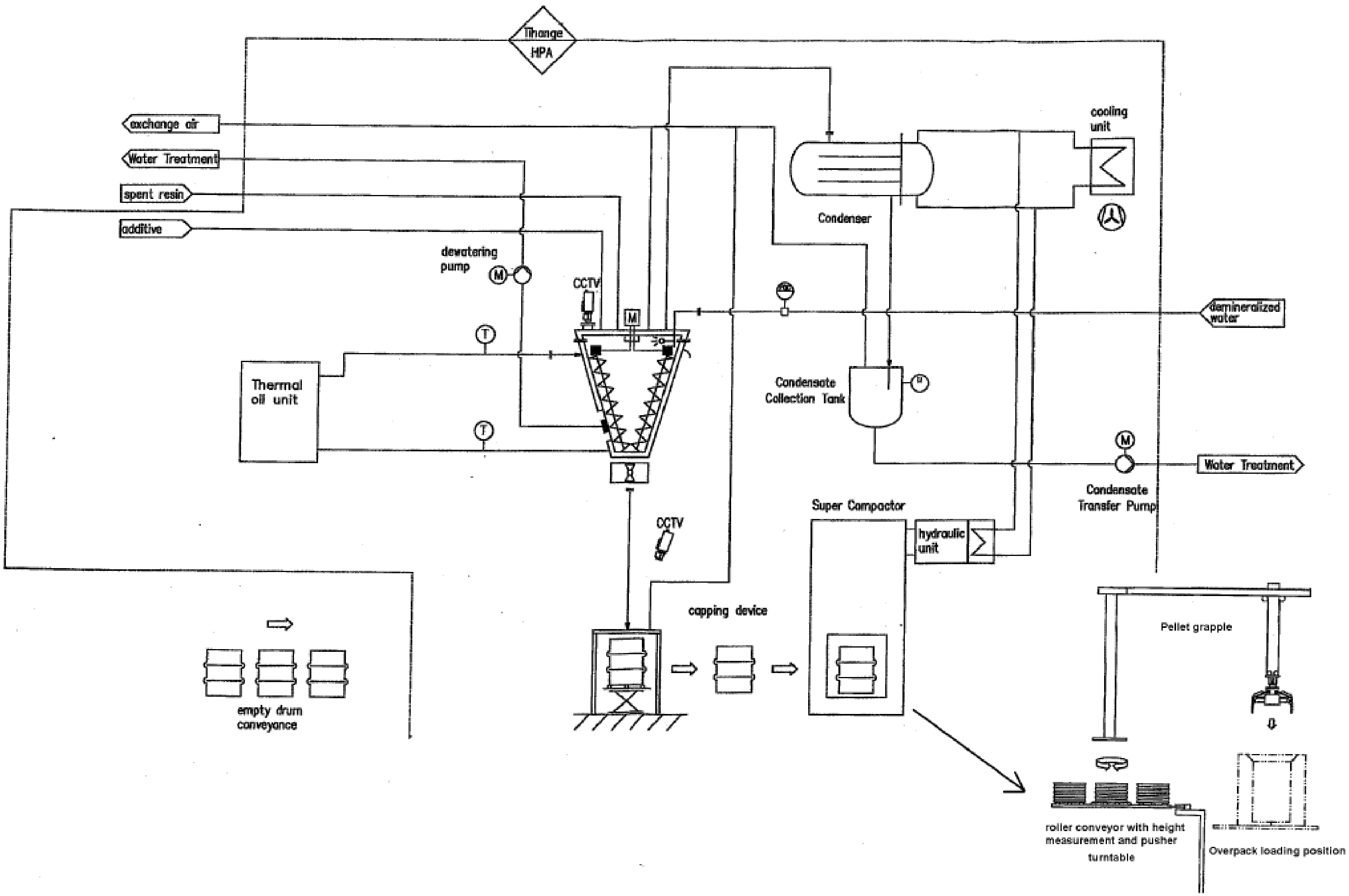

Fig. 3. Tihange NPP – Spent Resin Hot Compaction Conditioning Process – Simplified Flow Diagram

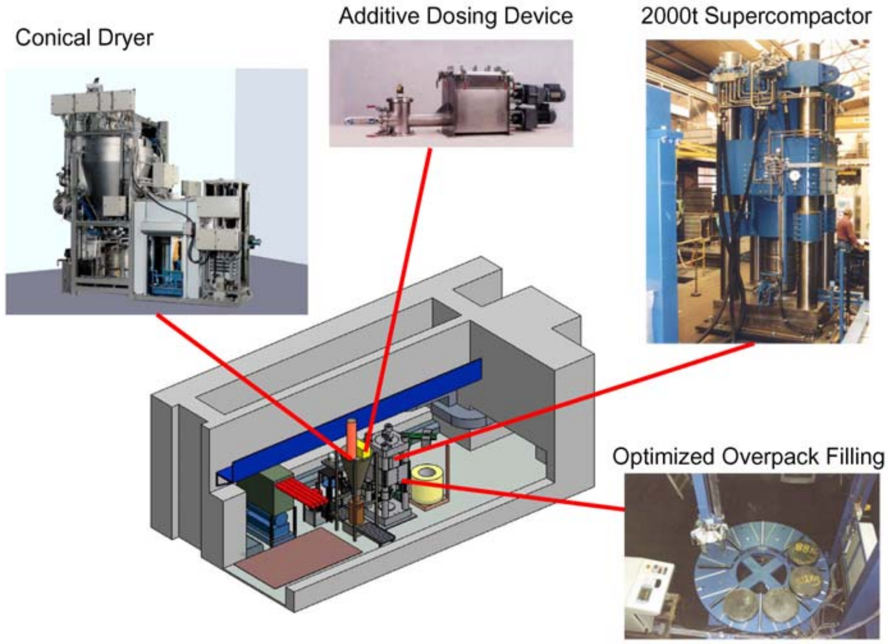

Fig. 4. Resin Hot High Force Compaction Process for Tihange NPP in Belgium

a. Resin Feeding and Dewatering
The resins at Tihange NPP are stored in tanks and will not be dewatered and filled in drums prior to treatment. Actually, the resin storage tanks are located above the conical dryer, so the resins can be routed by gravity into the dryer. Therefore a piping connection of the drying vessel replaces the drum lift and docking equipment used at the German plant. The pre-treatment step of the dewatering of the resins will be performed by a special device directly in the drying vessel prior to starting the drying operation.

b. Additive Dosing Device
Subsequent to the results of the test trials for the process modifications, a dosing device has been added to the system for adding the exact volume of additive (powdered polypropylene) needed into the drying vessel for mixing in the resin material prior to release for compaction.

c. Optimized Overpack Filling System
The resulting pellets from the Resin Hot High Force Compaction Process are considered relatively similar in terms of height, weight and dose rate. The overall duration of the resin conditioning campaigns and installation maintenance activities will be shorter than 2 months per year. Therefore, in addition to resin conditioning, the compaction system of the installation is considered to process also miscellaneous other solid waste streams.
In order to guarantee an optimized filling grade of the final overpacks, a selection table for buffer storing of pellets has been added to the system.

Process Specific Data and Performances

- **Volume Reduction Factor**

The dried resins are loaded into 190 liter drums which, after receiving a lid, are supercompacted. The pellets are then piled up into the 400 liter drums licensed for final disposal. The void volume between the pellets and the drum inner walls is filled with grouting mortar.

The overall volume reduction, i.e. ratio :

$$\text{VRF} = \frac{\text{Initial volume of wet resins to be conditioned}}{\text{Total volume of 400 liter drums required by the conditioning}}$$

, is predicted to lay in the range 1.5-1.8 pending upon the conservatism levels attributed to some parameters such as :

- the specific weight of the to be conditioned wet resin;
- the specific weight of the end product.

Similarly, the weight of compacted dried resins is predicted to lay in the range 193-205 kg/400 liter drum.
The so obtained VRF, even assessed on the basis of conservative assumptions, largely exceed those obtained by cementation processes and immobilisation processes in organic matrixes, such processes exhibiting VRFs < 1.

- **Processing Rate**

At Tihange NPP, the system is designed to process the maximum yearly resin production ($12m^3$) within 26 days. This criterion basically impacts the sizing of the conical dryer.

- **Layout Requirements**
  - Ground floor surface area : 13 x 7.5 m^2
  - Elevation (max) : 6.2 m

CONCLUSIONS

In more than 10 years successful commercial operations at the German plant, more than 3 800 drums of resins have been processed. A Volume Reduction Factor (VRF) of 4:1 has been achieved by using this process. The equipment has been proven to be a reliable technology with reasonable operation and maintenance cost.

The new application of the process and the equipment for a use in the PWR plant in Tihange, Belgium, demonstrates, that the process can be adapted for the use in other types of plants by using the same basic equipment. In an environment of very limited space resources for interim storage on site and the absence of an operating final repository site, the process exhibits the following key advantages:

- Achieving a Volume Reduction Factor up to 4:1 for the interim storage instead of growing the volume, i.e. instead of processes leading to VRF < 1;
- Achieving a water free end product;
- Creating a flexible waste product for interim storage, which can be retrieved, packed in drums or cubic containers according to future requirements or reclassified in terms of activity decades later;
- Utilizing well proven standard technologies like drying and compaction;
- Enabling, in the case of Tihange NPP, the grouting of the resin pellets with a mortar already qualified for the grouting of compacted solid waste pellets, i.e. avoiding, so, the complex and heavy procedure of a new recipe qualification;
- Flexible use of the system components also for the supercompaction of other operational solid waste streams outside of the resin conditioning campaigns.

ACKNOWLEDGMENT

The authors are grateful to Mrs M. Paquet for her support in preparing this paper and achieving a high editorial quality.

REFERENCES

[1] KONTEC ’93 Conference Transcript
E. Grundke, H.-D. Harass: Conditioning Radioactive Waste at the Point of Origin

[2] KONTEC '07 Conference Transcript
Experiences from over 10 years operation of the Resin Hot High Force Compaction as well as new applications for PWRs