Direct Encapsulation of Spent Ion-exchange Resins at the Dukovany Nuclear Power Plant, Czech Republic - 12367

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ABSTRACT

At the Dukovany Nuclear Power Plant there are large amounts of spent ion exchange resins contained within storage tanks. These resins are a product of the operation of an Active Water Purification System within the Power Plant. Activity levels of the resins are in the range of 10^5 to 10^6 Bq/l and the main isotopes present are Co-60, Cs-137, Mn-54 and Ag-110m. In order to maintain storage tank availability throughout the planned lifetime of the Power Plant these resins must be removed and disposed of safely. The storage tanks do not have an effective retrieval route for the resins and the installed agitation system is inoperable. A proven system for retrieving and directly encapsulating these resins to a standard required for the Czech repository is described, together with an overview of operational performance.

INTRODUCTION

Approximately 250m^3 of spent Ion-exchange resins are stored in a tank within the auxiliary building that serves Units 1 and 2 at the Dukovany Nuclear Power Plant in the Czech Republic. This tank is one of a suite that makes up the storage facilities for these wastes generated from the Active Water Purification system.

The circular tanks are installed within concrete cells and were not designed with an engineered waste removal route. Main access to the tank internals is via an inspection cover that is radially offset from the centre of the tank roof. There is only 1.5m headroom between the tank roof and the ceiling of the concrete cell, which complicates the deployment of any retrieval equipment.

Pumped transport of resins over long distances has also been difficult historically, without significant dilution and subsequent generation of secondary liquid wastes. Any engineered solution to the transport requirements for resins needed to address this issue to minimise the waste volumes produced.

Disposal of the spent resins can also be problematic as a result of issues surrounding encapsulation of organic material. This is less of a problem in the Czech republic and Slovakia as there is an approved packaging form for medium level radioactive wastes of this nature.

Within the project scope, several activities are being performed including withdrawal, treatment and processing of spent ion exchange resins from the storage tank. The final waste form is solidified within a 200l drum, which is subsequently transported to the Czech repository. Processing the waste in this manner frees up tank capacity to facilitate extended operational life of the plant, whilst reducing the potential hazard posed by large volumes of mobile waste.

METHOD

To overcome the challenges associated with access, transport of spent ion-exchange resin, secondary waste and final disposal a number of options were considered taking into account our previous experience of similar wastes.

The primary concern was the transport of the material, as this has caused problems in the past when attempting to transport resins over longer distances. Therefore, options that reduce the transport distance required were favoured.

The secondary concern related to effectively retrieving the spent resins from the tank in bulk. This issue required design and engineering effort to address, whilst avoiding significant impact on the overall programme to retrieve the wastes over a 2 year programme.

Production of the final waste form was not a concern, as a licenced encapsulation material was available (SIAL® matrix developed by AMEC Nuclear Slovakia) as was the equipment for producing the packages.

Overview

In order to address the primary concerns for the project a method was developed that placed the encapsulation process in close proximity to the tank containing the ion-exchange resin. This approach had been used successfully at other locations without issue, and proven equipment was already available that could be deployed for this purpose at short notice. Utilisation of this equipment provided significant flexibility with regard to the methods used for retrieval and pumping of the resins.

Trials were undertaken to establish an appropriate retrieval technique, drawing on prior experience of handling similar waste forms at other sites. The results of these trials were then used to develop a remotely operated bulk retrieval process. During the development and manufacture of the bulk retrieval process, the methods developed during the trials were deployed on an on-going basis. This approach allowed waste to be retrieved and treated (albeit at a lower rate) whilst the bulk retrieval system was being readied.

A system was then developed and installed to retrieve, pump, dewater and dose the resins directly into 200l drums the resins in bulk. Following sampling and analysis these drums are then encapsulated by mixing the dry encapsulant material with the resins and a metered quantity of water. An overview of this process is shown in
Fig. 1.

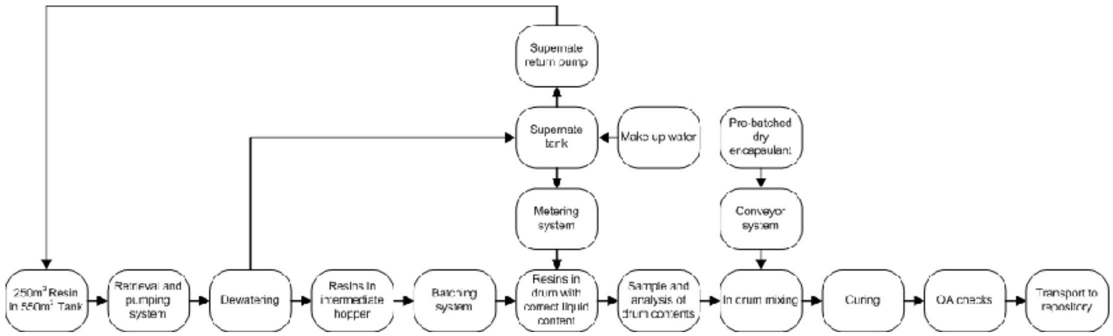

Fig. 1. Process Overview

Pumping system

The pumping system utilised consists of the suction nozzle and it's deployment system, coupled with a pump to provide the transport mechanism for the resins. The suction nozzle and deployment system were installed inside the tank and a diagram depicting this component can be seen in Fig. 2. A key requirement of the design was that it had to be installed by hand in limited working space.

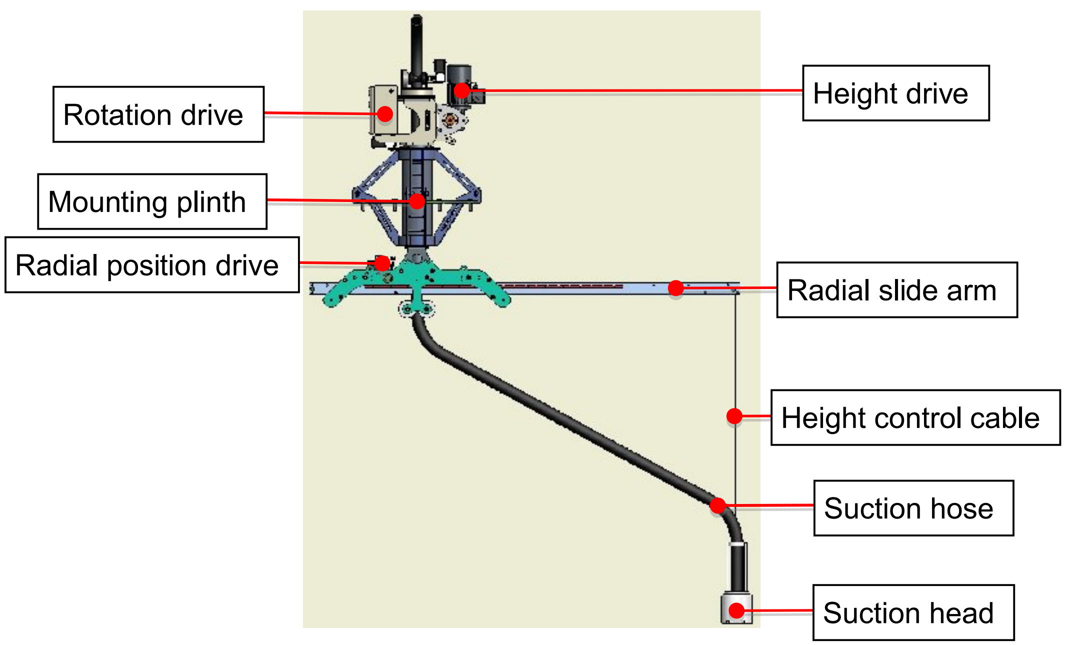

Fig. 2. Pumping System

Full coverage of the tank internals was provided by a combination of rotary, radial and vertical motions with each axis operated by gear reduced remotely controlled electric motors. CCTV equipment was installed inside the tank to remotely monitor operations. The technical details of the deployment equipment and the suction nozzle are proprietary.

Experience at other sites, backed up with trials at Dukovany, resulted in the selection of a rotary lobe pump to transport the resins, due to the to this designs ability to lift and pump particulates in an effective manner. The pump was installed on the top of the tank and is a commercial item.

Dewatering and dosing system

To avoid the need to transport the resins again after retrieval, the dewatering and dosing system was designed and manufactured as an integrated unit, comprising a hopper, dewatering screen, supernate tank, drum filling system, weighing system, and dosing system. This can be seen in Fig. 3.

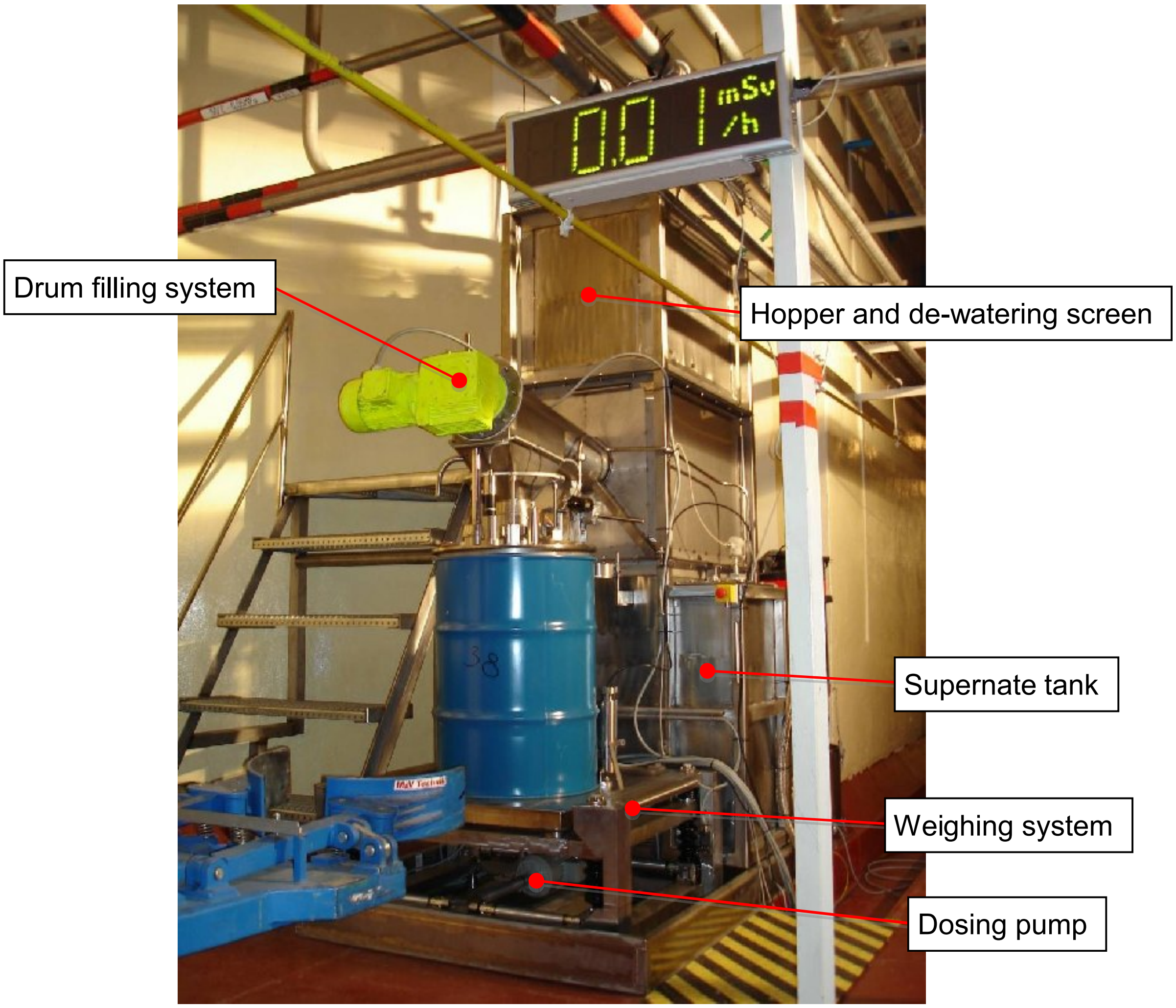

Fig. 3. De-watering and Drum Filling System

The spent ion-exchange resins enter the system at the top of the picture and are dewatered under gravity. The water is collected in the supernate tank for re-use to accurately dose the resins with a metered amount of water, in order to produce the correct water content for subsequent encapsulation. Surplus supernate is returned to the source tank. Make up water is also available should the need arise.

The drum filling system meters the spent resins into the drum by dry weight.

Encapsulation system

The encapsulation system that was utilised was a standard system that had been developed for use with similar waste forms. The process avoids the need for ready mixed encapsulant as this is added to a drum that contains the correct amount of water. The dry encapsulant is pre-batched into bags that contain the correct amount of material for each drum. The mixer paddle is not lost, it is withdrawn after each mix. This portable system has been utilised on a number of sites and is operated remotely to maintain radiological safety.

The encapsulant used was the AMEC SIAL® material, which is an Alumino-silicate based geo-polymer, licenced for disposal in the Czech repository with spent ion-exchange resins.

Fig. 4 illustrates the key components of the encapsulation system.

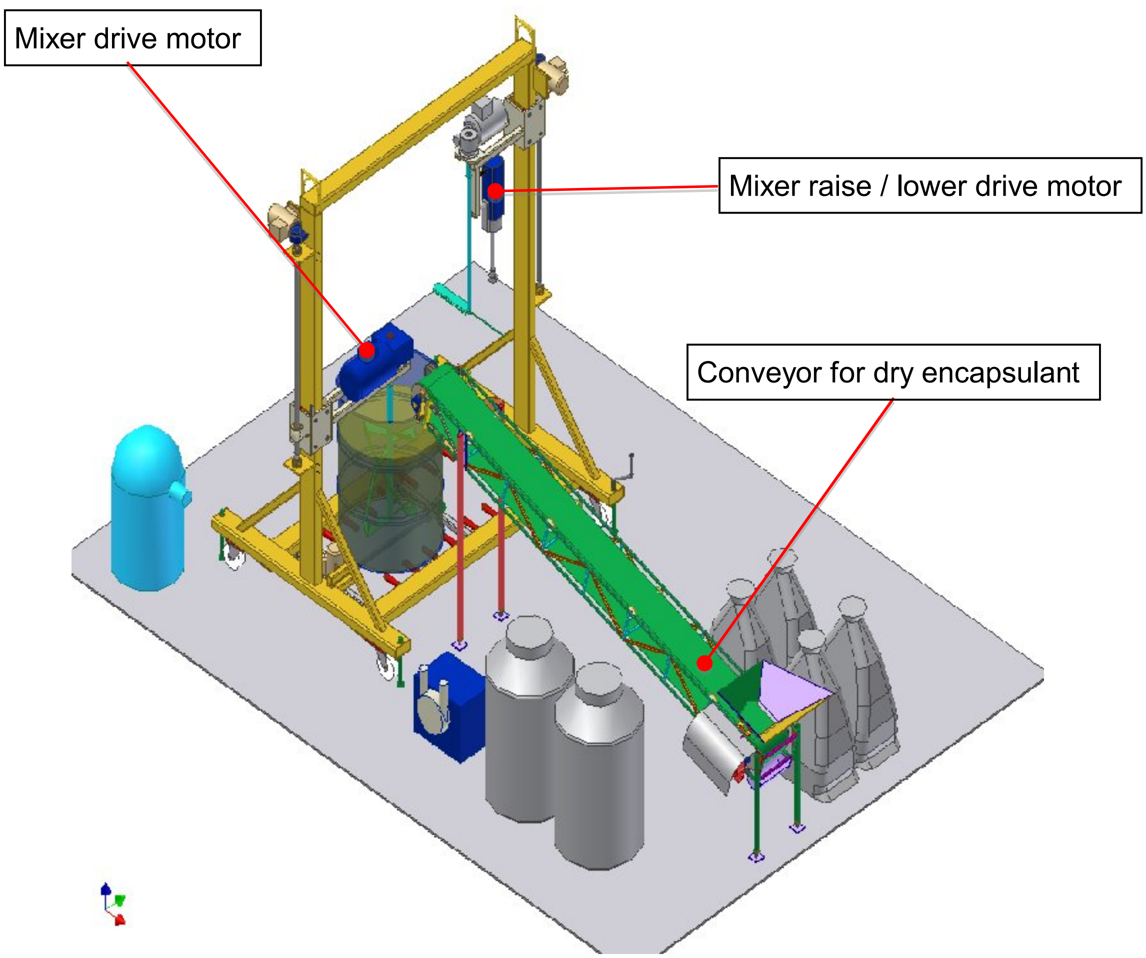

Fig. 4. Encapsulation System

This equipment has proven to be particularly robust with no failures observed during operations to date.

RESULTS

Throughput

Trial works to retrieve and encapsulate the resins commenced in September 2010 and ceased in December 2010. During this period 21,600kg of resins were retrieved and encapsulated, resulting in the production of 240 drums each with an average waste loading of 90kg. Additionally 19 further drums were produced containing sludges from another plant.

Full production commenced in February 2011 and as of the end of October 2011 71,640kg of resins have been retrieved and encapsulated, resulting in the production of 796 drums with an average waste loading of 90kg per drum.

Retrieval of a further 14,760kg of resins is scheduled for the period November 2011 – December 2011 which is anticipated to produce a further 164 drums.

The limiting factor for production rate is the analysis of the resin samples.

Product quality

Product quality requirements for the repository dictate compressive strength and leach index requirements as follows:

Compressive strength: >10MPa
Leach index: <4% (ISO 6961)

Actual measurements significantly exceeded these requirements as follows:

Compressive strength 19.0MPa (min) 34.7MPa (max). 10MPa achieved within 24 hours curing time.
Leach index: 0.03% (min) 0.65% (max) (ISO 6961).

All waste packages exceeded the repository quality requirements by a significant margin.

DISCUSSION

Experience gained from this and other projects has highlighted some common challenges relating to the treatment of ion-exchange resins and sludges. There are common approaches that can assist in overcoming these challenges.

1. Transport resin / sludge type waste over as short a distance as possible to avoid issues with line plugging.
2. Transport these wastes once and once only wherever possible.
3. Try to keep the treatment process as simple as possible. With sludge or resin handling equipment consider the physical properties foremost – radiological issues can be addressed within any subsequent design.
4. Consider the use of dry-mix technologies. This avoids the requirement for expensive and complicated grouting plant.

5. Avoid the use of make up water for transport purposes if at all possible – it introduces secondary waste that needs to be treated at additional cost.
6. Consider alternative disposal techniques. SIAL® is AMEC's preferred technology as we developed it and understand it well – additionally the waste loading factors are much higher than for cement.
7. Consider final waste volumes when selecting the disposal technique. Disposal costs will probably make up the bulk of the total life-time cost for any retrieval / encapsulation project.
8. Have a selection of ion-exchange resin/sludge retrieval techniques available – it is difficult and time consuming to develop a technique that will cope with all eventualities, particularly when there are unknown conditions. It is much more productive to switch retrieval techniques as appropriate to deal with evolving conditions.