RETRIEVAL OF SALT, SLUDGE AND IX RESIN FROM NPP STORAGE TANKS

B. G. Christ, R. Rieck, H. Witing
RWE NUKEM GmbH
Industriestrasse 13, D-63754 Alzenau, Germany

ABSTRACT

This paper describes the development of a new Tank Emptying System (TESY) by RWE NUKEM for liquid NPP waste. The system deals with the dissolving and transferring of stored radioactive salt solutions, salt deposits, spent ion-exchange resins and sludge generated during nuclear reactor operations. The technique used allows to deploy the new tank emptying system for a variety of tank constructions and problematic waste materials. The core component of the new developed equipment is represented by a remotely operated submersible crawler unit which facilitates local heating and dissolution of salt as well as dispersion of sediments and evacuation of resulting solutions, respectively suspensions. An integrated pumping system acts to send the resulting liquids to downstream treatment facilities.

INTRODUCTION

A considerable number of the world's Nuclear Power Stations are designed to accumulate the arisings of liquid waste in tank facilities without further treatment and to store this material for the NPP´s life time.

To fully use the net volume of the storage waste tanks, evaporation effluents are further highly concentrated inside the tanks by pH-adjustment and subsequent salt precipitation, whereas sludge and IX resin waste is drained in the tanks to effectively store only the wet solid material.

As a result of unforeseen waste arising during NPP´s operation, and also caused by extension of scheduled NPP´s life time meanwhile many tanks reached their storage capacity. In addition, some country's storage policy has changed recently from liquid waste tank storage to near surface or deep geological storage of immobilized waste.

Therefore, there is a current need to retrieve the aforementioned stored tank waste for treatment, off-site storage and to re-provide storage capacity in the tank facilities for future arisings of NPP operational waste. Whereas advanced techniques for volume reduction of liquid waste are widely available, appropriate techniques for the retrieval of the specific wastes are lacking.

THE TANK EMPTYING SYSTEM FOR KOLA NPP

In 2003 RWE NUKEM was awarded the contract for the design, delivery and commissioning of an appropriate tank emptying system.

Evaporator concentrates, radioactive salt precipitates, spent ion-exchange resins and sludge from nuclear reactor operations are stored at the KOLA Nuclear Power Plant, Russia, in stainless steel tanks within concrete cells in two storage buildings located in parallel on the site. Due to the prevailing radiation level there is limited access to the tanks. Emptying equipment can only be inserted into the tanks from the intervention corridor via a flange, as can be seen from Fig. 1.

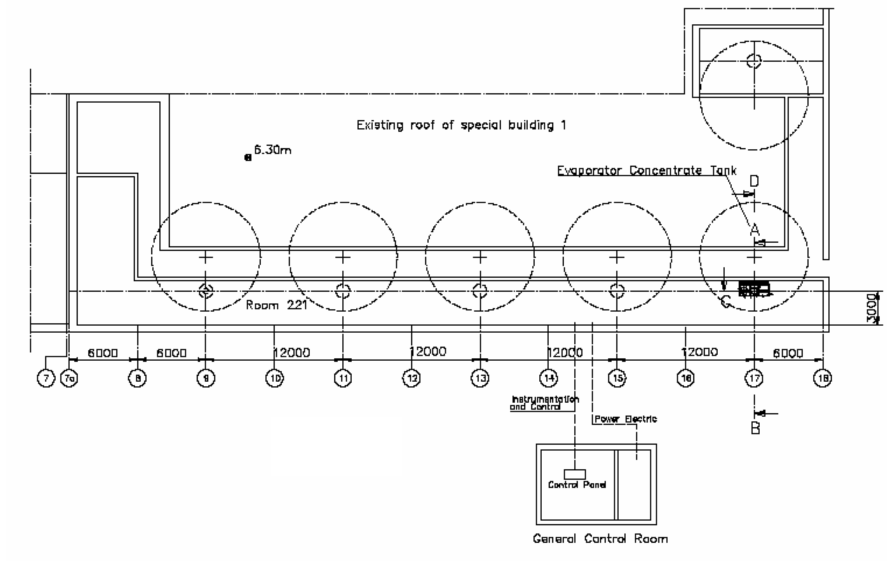

Fig. 1 Arrangement of storage tanks for liquid waste at KOLA NPP

There is one flange per tank located eccentrically on the top. All tanks have a flat bottom and vary in diameter and height. Also the inside diameter of the access opening varies from 527 to 800 mm.

Design Basis

Since the tank emptying system must suit all storage tanks, the following reference sizes relevant for dimensioning the emptying system have been chosen:

• Maximum tank diameter	10.0 m
• Maximum cylindrical height	7.8 m
• Wall/Bottom thickness	4 to 6 mm
• Access flange minimum inside diameter	527 mm
• Adapter flange inside diameter for emptying system	unique in size
• Access flange/tank center eccentricity	up to 3.0 m
• Height of tank bottom to the operating floor	max. 9.6 m
• Level of solids in tank	max. 5.46 m (70%)
• Level liquid in tank	max. 7.02 m (90%)

During the years of reactor operation concentrated salt solutions, spent ion exchange resins and sludge were transferred separately to the different tanks to be stored intermediately.

During storage salt further crystallized and settled on the bottom, so did solids from sludge and IX resin suspension. The actual consistency of the sediments is not exactly known and may range from muddy to almost solid. According to a visual inspection through a hole in the sidewall of one tank a layer of ~80 mm salt had crystallized there on the sidewall. The sump had a height of ~1 m and consists of easily movable mud with a crystal crust of ~30 mm on top.

According to RWE NUKEM's broad experience in radioactive liquid tank emptying it is best to mobilize the salt and sediments locally for removal and to pick them up as salt solution or suspension respectively from the point of mobilization. Thus, the emptying concept finally chosen comprised as a main component a "Crawler" with jet nozzles for agitation and a suction head to pick up the solution or suspension respectively.

This concept furthermore deploys a glove box as containment on top of the tank access flange which

- avoids spread of contamination
- allows to install and exchange parts which are especially effected by erosion
- discloses the use of off-the-shelf components due to the additional barrier
- reduces cost of spare parts and decreases related delivery time
- reduces operating time in the intervention corridor and
- increases the safety of operation.

Arrangement of the System

Figure 2 shows in principle the arrangement.

The glove box (1) is located on the upper side of the concrete ceiling and is connected to the access opening of the respective storage tank via a tube. The connection tube (2) is equipped with spray nozzles and an outlet connection for the evacuated off gas. The crawler (5) and submersible pump (6) are connected to a pre-assembled hose (7) when inserted to the tank by means of the chain hoist (3). A heater (8) is mounted on the rear outside of the glove box. Instruments and valves bearing radioactive liquid are positioned inside the glove box. The switch cabinet (9) is located outside on the side wall of the glove box. A TV-camera & 2 spotlights (10) are arranged inside the tank to determine the crawler position.

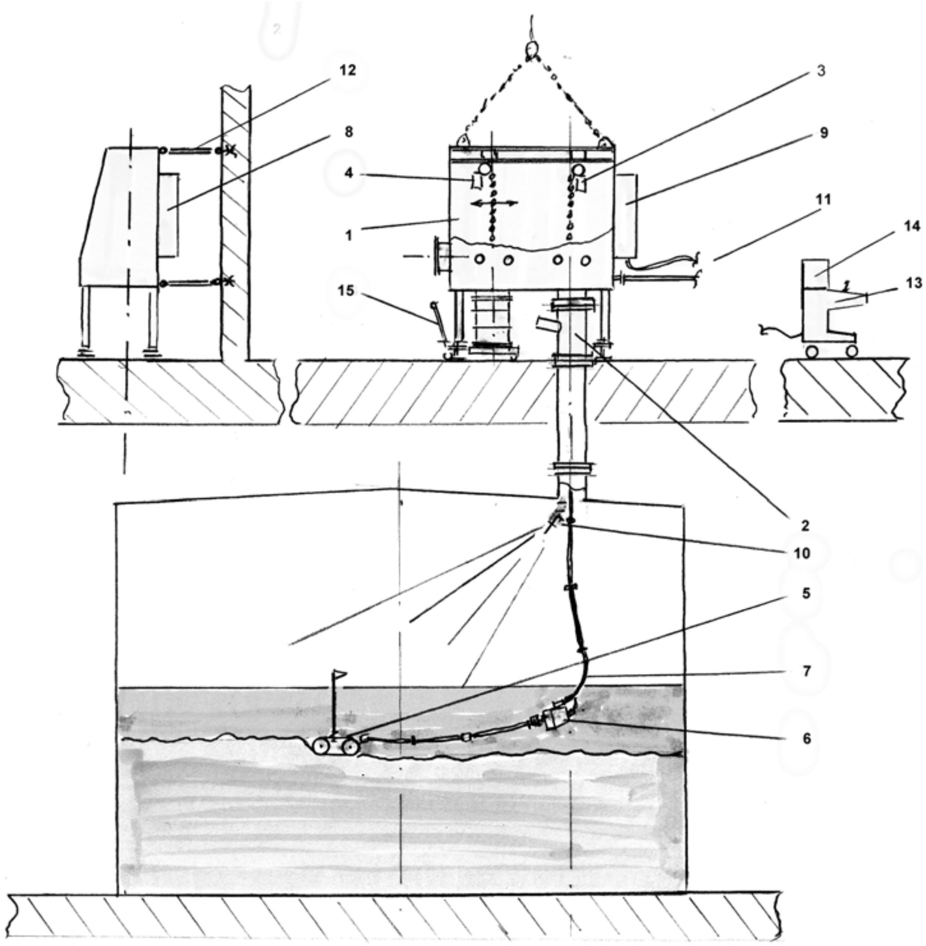

Fig. 2 Tank Emptying System (schematic)

The hydroxide dosing unit is installed in a fixed position inside the intervention corridor (not shown in Fig. 2). Outside the glove box, pipes are used to connect the emptying system to the product transfer lines. Flexible hoses and cables are used for connecting media, electrical power and control lines (10).

In order to withstand seismic events and to achieve sufficient stability the glove box is fixed to the adjacent concrete wall using detachable braces (11). The switch cabinet includes necessary push buttons and switches for the system installation. The emptying process is operated remotely from a panel board (12) and TV monitor (13) in the central control room.

The Crawler, a Main Component

The chain crawler, see Fig. 3, operates under water and is designed to fluidize and pick up solids from all positions within the tank. Two pneumatic motor chain drives allow moving on solids and sloped surfaces. Different chain speeds allow the steering similar to an armoured tank. The front end of the crawler is equipped with a suction head and jet nozzles with remotely adjustable inclination. A flexible flagpole fixed on the crawler allows the operator to locate crawler position under water using a TV camera & spotlight arrangement.

Main Data

Dimensions:	~460mm x ~400mm x ~900mm (W x H x L);
Weight:	~200kg
Drives:	2 chain drives, pneumatic motor, ~300mm drive wheel diameter, ~3m/min max. speed
Connections:	1 suction hose, 1 quick connector for liquid return
Suction head:	width 250 mm, 40 mm clearance from the bottom line, screen size 8X8 mm.

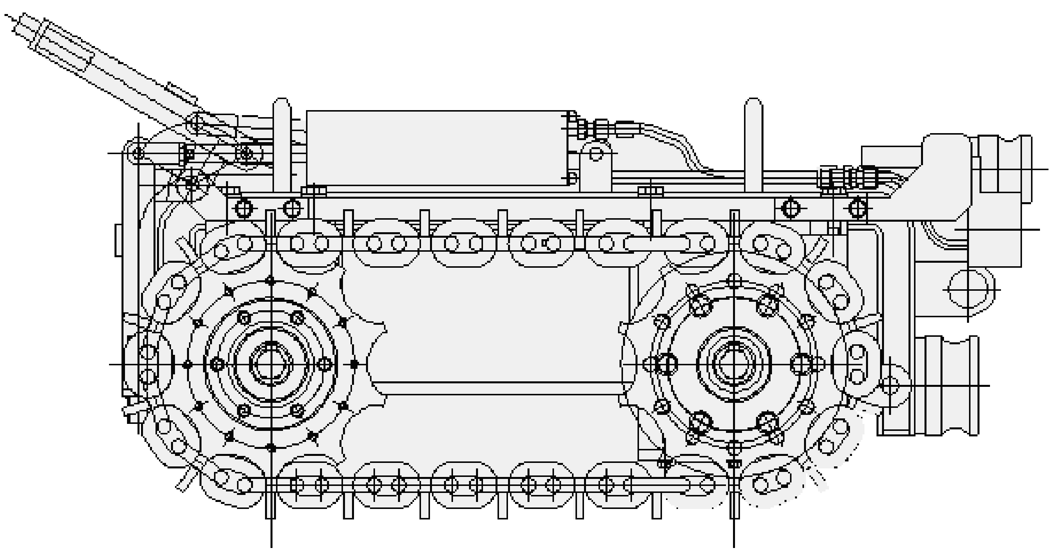

Fig. 3 Submersible Chain Crawler for tank emptying

Tank Emptying Process

A salt concentration of > 115g/l is required for downstream liquid waste treatment. From laboratory tests recently performed it is known that the maximum of dissolving salt is achieved at a temperature of 70°C. Due to equipment design the temperature at the suction inlet is limited to 60°C. To further increase dissolving efficiency caustic conditions of pH 11 to 12 must be maintained by the emptying system. The heat tracing > 60°C on the transfer pipe to the treatment facility is mandatory to avoid re-crystallization.

The following parameters are relevant for effective dissolving of the salt deposits:

- increased temperature
- large salt surface
- high gradient of concentration and
- strong liquid motion.

The anticipated flow velocity within the pipes and hoses is >1.5 m/s to ensure solid material transport. In horizontal and down flow pipe sections the velocity is consciously reduced to >1 m/s by increasing the pipe diameter in order to minimize erosion.

Due to the abrasiveness of the sediments transferred, especially the suction head of the crawler, the submersible pump, and pipe elbows are exposed to abrasion and may have to be repaired or replaced periodically. Consequently, precautions like use of grey cast iron and nitrile-rubber lining, reduction of the velocity where possible and maintaining access to all sensitive parts, are considered in the design to avoid frequent component exchange due to material erosion.

The transfer liquid for sludge and ion exchange resin is practically chemically neutral. The solid concentration during transfer varies between 5-25wt%, an average of ~ 15wt% appears possible.

The parameters which affect the efficiency of IX resin and sludge transfer are:

- sufficient fluidization of the sediments and
- sufficient liquid to avoid pipe clogging.

On one hand, for salt removal, it is not appropriate to heat up the entire tank volume. On the other hand it is not possible to completely fluidize all ion exchange resins and sludge in the tank for removal. RWE NUKEM decided therefore to apply the increased temperature and pH 11 to 12 and to agitate the sediments locally. The sediments are then picked up in form of a solution or suspension directly at the point of their mobilization.

To reach all positions for material mobilization inside the tank RWE NUKEM has chosen a tracked vehicle, so-called "crawler", equipped with a suction head used in combination with a submersible centrifugal pump, both connected to each other via a flexible suction hose. The crawler can move the suction head to any location inside the tank. As the submersible pump is not self priming both the suction head and the pump have to be kept under the liquid surface during operation. It is proposed to maintain a liquid layer of ~1 m on top of the solid material.

In order to determine the crawler's location and the supernatant level the crawler is equipped with a flexible flagpole that heads through the liquid. A TV-camera and spotlights are installed removable inside the tank.

Emptying Methods

Two basic emptying methods are deployed:

- Removing the sediments in ~0.3 m layers; this method requires numerous crawler movements.
- Removing the sediments going straight down to the bottom using a special suction head for the submersible pump initially. Thereafter the crawler is connected to the submersible pump and used moving horizontally towards the tank wall; in this case the sediments must trickle well similar to sand.

The appropriate selection of the emptying procedure depend on the actual consistency and behaviour of the crystallised salt or sediments. After installing the emptying equipment locally in the intervention corridor the emptying is performed remotely from a panel board and TV monitor located in the central control room, interrupted only for adding product hose extensions in the glove box.

System Dimensioning

The main component affecting the extraction rate is the submersible centrifugal pump and the size of the transfer pipeline. Due to the limited access dimensions the size of the pump and the related flow capacity are limited, too. From other RWE NUKEM's full scale tank emptying tests determined satisfactory transportation of ion exchange resins and sludge via a DN50 pipeline over a distance of 500 m at a velocity of 2-3 m/s. An average solid concentration of 15wt% had been achieved. Based on these parameters a submersible centrifugal pump with a throughput of > 20m³/h and operating pressure of >25 m water have been selected for the KOLA emptying system.

Depending on the dimensions and distance between the emptying system and the treatment facility a booster pump may have to be installed in the transfer pipe line.

The removal capacity is for

- Evaporator concentrate solutions > 3600 m³/ yr.
- "Decontat" > 936 m³/ yr.
- Solutions of crystallised deposits > 2664 m³/ yr.

Which enables the KOLA NPP to empty the tanks in the foreseen reasonable time.

CONCLUSION

Stored waste of Nuclear Power Plant, i.e. spent radioactive salt deposits, ion-exchange resins and sludge, can be emptied and transferred out of the tank with the RWE NUKEM´s new TANK EMPTYING SYSTEM (TESY). The sediment, crystallized and settled during storage, will be agitated with increased temperature and suitable pH value and then picked up in form of a suspension or solution directly at the point of mobilization.

The new TANK EMPTYING SYSTEM concept enables efficiently to retrieve stored salt and other sediment waste, reduces operating time, safes cost for spare parts, increases the safety of operation and minimizes radiation exposure to personnel.