

**LIQUID RADIOACTIVE WASTE SOLIDIFICATION SYSTEM FOR TIANWAN
NUCLEAR POWER PLANT, P. R. CHINA**

K. Froschauer, W. Lingens
RWE NUKEM GmbH
Industriestrasse 13, D- 63754 Alzenau, Germany

X. Long
RWE NUKEM GmbH Representative Office Beijing
CITIC International Bldg., Suite 26-A, 19, Jianguo Menwai Dajie, 100004 Beijing, P. R. China

ABSTRACT

As a part of the construction of the Tianwan Nuclear Power Plant in the Lianyungang Province, China, in August 1999 RWE NUKEM GmbH was awarded a contract for the design and delivery of a liquid radioactive waste solidification system. The system is intended for the solidification of liquid radioactive waste generated during the operation of the NPP. The two units of the Tianwan NPP pressurized water reactors supplying 1000 MW each unit are scheduled to be put into operation in 2004 (first unit) and 2005 (second unit). Each unit will be equipped with an identical constructed solidification system for the solidification of approx. 100 m³/year of low active evaporator concentrates as well as low and medium active ion exchange resins. The final waste package is a reinforced concrete cask, suitable for transportation and subsequent interim storage or final disposal. This paper describes in principle the technique of the solidification plant and the experience gained by RWE NUKEM GmbH during the performance of the project in China.

INTRODUCTION

During operation of the Tianwan Nuclear Power Plant liquid radioactive wastes will be generated, which comprises the following constituents:

- Still Residue
- Salt concentrates from evaporator
- Slime from water processing
- Pulp of spent ion exchange resins

These liquid radioactive wastes need to be solidified prior of their final disposal. The solidification of the liquid radioactive wastes ensures safety during intermediate storage on site as well as during their transportation, and at final disposal. Since the cementation of low and intermediate level liquid waste is one of the most common solidification methods, widely applied in the world, this process has been chosen do be most appropriate for this project as well.

TECHNICAL DESCRIPTION

The design basis for the solidification plant is based on the waste quantities generated during the operation of the Nuclear Power Plant as following:

- Still residue (evaporator concentrates) with salt contents up to 400 g/l 80m³/year
- Spent ion exchange resins 25m³/year

Table I shows the specific activity and the radionuclide composition of the two different forms of liquid waste.

Table I Radiation parameters of waste

Radiation Parameter	Spent Ion Exchange Resins	Still Residue (Evaporator Concentrates and Slime)
Specific Radioactivity, GBq / m ³	100	160
Radionuclide composition, %		
Corrosion Products (Co 60)	24	11
Iodine (I 131)	2	4
Cesium (Cs 137)	35	85
Other nuclides (Sr-89)	39	< 1

The plant capacity ensures processing of the above mentioned quantities of liquid radioactive wastes within one year. Shutdown periods for maintenance, repair and inspection are considered. Each solidification system comprises the following functional subsystems:

- Cement storage and grout preparation
- Resin preparation
- In cask mixing
- Cap grouting of cask
- Radiation monitoring and cask transfer area
- Process control and instrumentation

The Fig. 1 and Fig. 2 show the principle process and its functional subsystems. The cement storage consists of a dust-tight, cylindrical steel silo. The cask to be filled has to be placed in the filling position and the cement loader has to be placed on top of the cask. The loading of the cask is performed by a special cement metering assembly, which allows to monitor and control the filling process of the cask from the control desk. The quantity of cement to be filled into the cask can be set down from the control desk, and when the desired quantity of cement has been reached the cask filling process will be

automatically stopped. Likewise the required quantity of cement is fed from the cement silo into the grout preparation system for the later cap grouting of the casks.

In the subsystem resin preparation the resins are made ready and available for cementation by recirculation and homogenizing of the waste volumes in the resin hold tank. The resin hold tank is fitted with an agitator for suspending the resin/water mixture prior to the waste filling of the cask. The still residue are kept in the still residue hold tank.

As soon as the cask is pre-filled with cement it is getting a bar code for the later identification. This is necessary already at this stage of the process, since the defined quantity of cement which was filled into the cask prior to the mixing process is depending on the type of waste later to be added and the related recipe. The pre-filled casks are then transported by roller conveyors to the in-cask mixing position. The lifting door of the mixing unit opens only after a bar code reader has identified the cask. Then the automatic tracking system can control all mass flows according to waste type and recipe. After the cask is located in the docking position and for ventilation barrier the lifting door is closed and the slide gate is open the mixing process can be started. The waste volume required for the cask to be filled is set up in accordance with the specified recipe and controlled via a coriolis flow meter from the control desk. The in cask mixer is a steel construction with a swinging boom. Fixed on the boom there is a large turning table, which holds the mixing tools, the drivers for these tools, the dosing mechanism for the liquid waste, the overfilling protection and the splash protection. As soon as the mixing process is started the liquid waste is filled into the cask, already pre-filled with cement and additives, and the lifting mechanism of the cask mixer moves the mixing tools into the mixing position. The stirrers of the cement mixing unit are formed in a special shape so that during the mixing process the cement product inside the cask is transported simultaneously from the top and bottom of the cask into the center of the cask. In addition to that the contrary turning direction of the stirrers ensures a homogenized cement product and largely avoids splashing. Upon completion of the liquid dosing the mixing process is continued for approximately 15 minutes before the mixing process is completed.

When the filling and mixing process is finished, the cask is moved forward on the curing conveyor, where it remains for curing. When the curing time is over the cask is moved to the grouting position below the grouting device. In the grout preparation plant the partial quantity of the still required complementary quantity for the casks is prepared. The cap-grouting then can be started while the exact quantity of grout is determined by means of a continuous measuring with a filling level gauge. An overfill protection responds as soon as the filling level has been reached. Then the cap grouting is completed and the curing time again is monitored by a timer function in the control system.

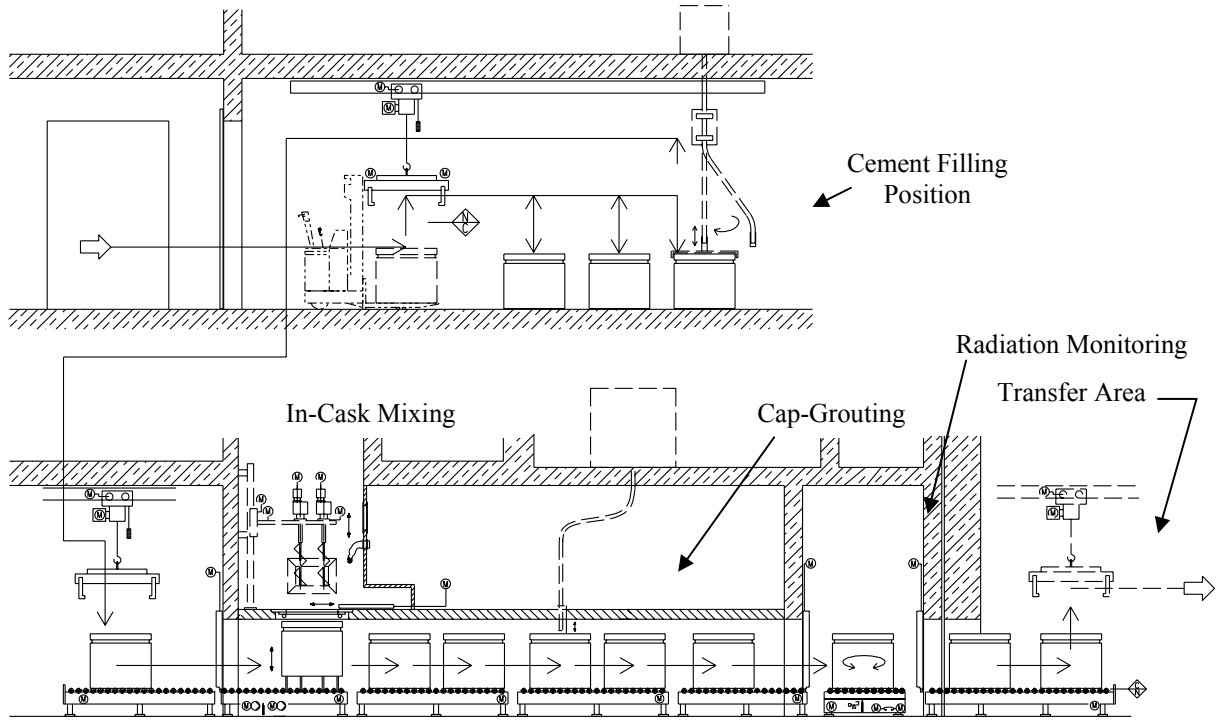


Fig. 1 Handling Layout of the Solidification Plant

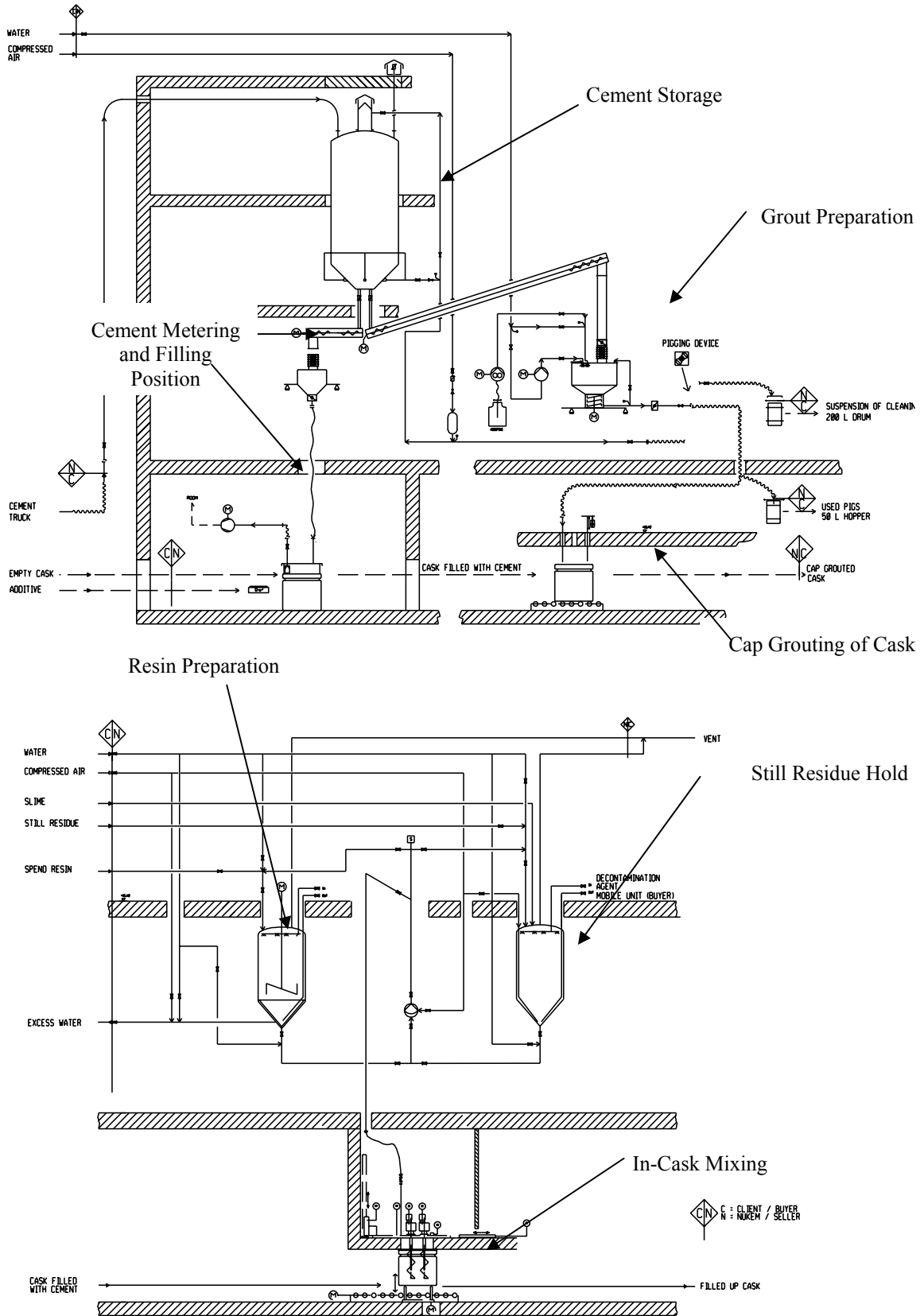


Fig 2 Principle process layout of the solidification plant

After the curing time is over, the casks are transported individually to the monitoring position. There the following measurements are performed during the monitoring procedure:

- Mass of the filled cask
- Surface dose rate
- Dose rate in a distance of 1 m from the surface
- Surface contamination

The mass of the cask is measured by an integrated weighing system in the turntable, the surface dose rate is determined by dose rate meters at following positions:

- Base of the cask
- Lid of the cask
- Three position at wall of the cask
- One position in a distance of 1 m from the wall at the half of the height

The surface contamination check is performed at the lid of the cask and at two position at the wall. The measurements must fulfil the requirements for transportation. Thus the dose rate level of the casks is low enough that the room can be entered. Therefore, the swabbing features can be taken away manually by the operator and monitored outside the cell. The positions for swabbing are not fixed and can be adapted to the experience gathered during the commissioning phase. Since the cask has a rough surface a wipe test with wipe test paper cannot be performed. Therefore, a scotch tape is used which fixes the contamination. The scotch tape is mounted in a cassette.

Table II presents the criteria for contamination check as given by the National Standard of the P. R. of China.

Table II Criteria for contamination check

Area to be analyzed	300 cm ²
Limit for β , γ and low toxicity α emitters	4 Bq/cm ²
Total	1.2 kBq
Limit for other α emitters	0.4 Bq/cm ²
Total	0,12 kBq

Further to the dosimetric parameters the following characteristics of the cement solidified waste form has to be met:

- Leaching rate for Co 60 $\leq 2 \times 10^{-3}$ cm / day
- Leaching rate for Cs 137 $\leq 4 \times 10^{-3}$ cm / day
- Compressive strength > 7 N / mm²

Other Parameters:

Incorporated wastes in the cement matrix $\geq 40\%$ by volume
Filling rate of Cask $\geq 95\%$ of its height

PROJECT EXECUTION

The kick off meeting for the project was held in April 2000 in Beijing. Four months later in August 2000 the basic engineering and in May 2001 the detail engineering was reviewed and has been approved together with the Chinese client and the involvement of the Russian design institute SPAEP in St. Petersburg, Russia. After the release of the detail engineering documents in October 2001 the procurement was started. The functional workshop test of the subsystems and components took place about one year later in October 2002. In January 2003 the first unit was shipped to the site in Lianyungang Province. Installation began in March 2003. After cold start up the successful acceptance test of the first unit is expected before the end of 2003.

The overall co-operation during the engineering and procurement phase as well as on site between the Chinese Customer and RWE NUKEM as the contractor was very positive. Due to the past performance experience of RWE NUKEM in the joint co-operation with SPAEP in various nuclear industrial projects in Russia as well as the experience gathered during the design and delivery of several radioactive waste treatment facilities to Chinese customers a good working atmosphere was established as the basis for the project performance. Not only the capabilities of the Russian speaking engineers at NUKEM but also the support through our Chinese representative office in Beijing, e.g. for the interface management, must be stated as a great advantage for the project works.

The execution of the installation work itself was performed by the Chinese customer under the professional supervision of experts from the contractor. To ensure an almost smooth progress of the installations a very detailed declaration of each single step of execution was necessary, thus quite comprehensive and very detailed installation and operating manuals had to be provided by RWE NUKEM.

The installation work was performed precisely according to the instructions and advice given by the contractor's supervisors. For example all pipeline installations, weld seams and mountings of equipment were performed tidily according to the installation instructions.

The receipt of goods and deliverables as well as the storekeeping of the goods were well organized by the customer. Also the working policy and motivation on the Chinese side was excellent. In case of urgent need the installation team even over night finalized outstanding actions during additional shifts.

Nevertheless the challenging situation to manage the interfaces between the three major parties involved, consisting of the Chinese customer, the Russian design institute SPAEP responsible for the general design of the Nuclear Power Plant and RWE NUKEM as the supplier of the solidification plant results in a significant delay of the project schedule. Also the customs clearance fully out of the influence of both the customer and the contractor was an additional reason for the some delay in the project, which to catch up was not possible during the overall project period.

With regard to the communication and correspondence between the responsible individuals the English language as the official contact and project language was clearly pre-defined. Regardless from time to time the communication especially on site during installation was requiring special efforts, such as gestures etc.



Fig. 3 Tianwan Reactor Unit 1 incl. machine room in the front and the waste treatment area left to the reactor

STATUS OF PROJECT

While the first solidification system was already delivered and successfully installed in the first half of 2003, the second system has just been shipped on site and is currently under installation. Functional test and acceptance of the first systems is expected to be finalized until end of 2003, for the second system the completion is expected in March 2004.



Fig. 4 In-cask mixer on the left and docking position underneath the mixer on the right

CONCLUSION

The integration of a Western Standard radioactive waste treatment facility, using proven technique to be integrated into a Russian design VVER-1000 Nuclear Power Unit can be seen as unique. But the more challenging circumstance in this connection is the realization of the project in the Lianyungang Province of the P. R. China as the location of construction of the NPP. For the project coordination, the reconciliation of engineering and management of interfaces these are challenging circumstances, taking into consideration cultural contrasts of the involved countries.