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AN ADVANCED LIQUID WASTE TREATMENT SYSTEM USING A HIGH EFFICIENCY SOLIDIFICATION TECHNIQUE

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ABSTRACT

An advanced system using High Efficiency Solidification Technology (HEST) was developed to treat PWR liquid waste and the first unit is operating in Taiwan (1) and a detailed design is being carried out for the second unit in Japan.

The HEST system consists of two subsystems, a super-concentration subsystem and a solidification subsystem. The super-concentration subsystem is able to concentrate the waste solution to a total boron content as high as 130,000 ppm prior to solidification. The higher boron content will result in greater volume reduction efficiency of solidification. The solidification subsystem consists of an in-drum mixing and a conveyor units. Representative features of this advanced system are as follows.

(1) Simple system:
The system consists of the super-concentration and cement solidification subsystems; it is as simple as the conventional cement solidification system.

(2) High volume reduction efficiency:
The number of solidified waste drums is about 1/2.5 that of bitumen solidification.

(3) Stable Package:
Essentially no organic material is used, and the final package will be stable under the final disposal conditions.

(4) Zero secondary waste:
Washing water used in the in-drum mixer is recycled.

This paper describes the outline of HEST technology, treatment system and pilot plant tests.

INTRODUCTION

Waste treatment technologies are intimately connected with the final disposal criteria. The Rokkasho Low-Level Radioactive Waste Center in Aomori Prefecture has been operating since December 1992. At first, only homogeneous packages such as liquid waste solidified with cement were disposed. With the opening of the Disposal Facility II in October 2000, heterogeneous packages such as metal pieces and filters, solidified with cement, can be disposed as well.

The fundamental goals in developing a radioactive waste treatment system are:
(1) reducing radioactivity release into the environment;
(2) reducing waste volume;
(3) obtaining a stable package for final disposal; and
(4) obtaining a simple system.
In addition to these factors, total cost reduction, including equipment and the final disposal fee, has recently been emphasized.

In order to achieve these goals, we developed "Slim Rad" and the first system has been in operation since 1996 at the site of the first ABWR (advanced boiling water reactor) (2). Slim Rad is a complete system which consists of off-gas, liquid and solid waste treatment subsystems as well as a waste package inspection subsystem for final disposal. Slim Rad was designed by utilizing our operating experience with the ABWR system and upgrading component capability with newly developed technologies. An outline of the system is shown in Fig.1. The main features of Slim Rad are listed below.
(1) Optimized system: The tank volume and waste treatment capacity are about 60% those of the previous system.
(2) Waste generation and volume reduction: Average waste generation per plant (1,350 MWe) is about 100 drum/year, which is 1/8 that of the previous plant.

One of the key technologies in this system deals with volume reduction and solidification of liquid waste. We have developed a drying and pelletizing system followed by a cement-glass solidification process, and two units are currently in operation in PWR and BWR plants. Our recent efforts to reduce liquid waste generation have emphasized the needs for a simpler and less expensive system with high volume reduction efficiency.

The advanced solidification system using High Efficiency Solidification Technology (HEST) was developed to treat PWR liquid waste. This system is simpler and has a higher volume reduction efficiency compared with the previous system, and it produces stable final packages and generates zero secondary waste.

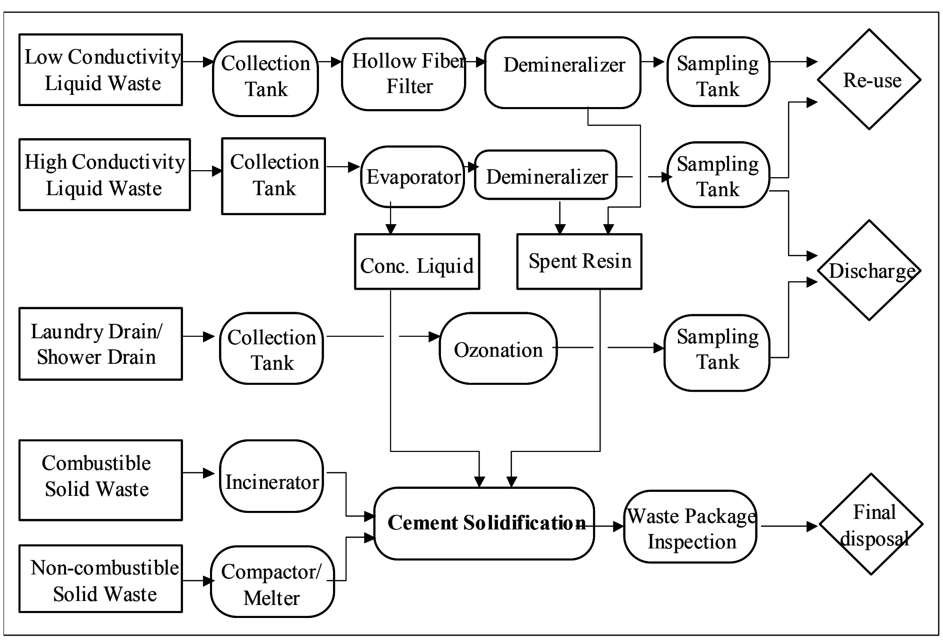

Fig.1: Outline of Slim Rad System

THE HEST PROCESS (1)

The main component of the PWR concentrated waste is borate. It is known that borate is a retardant for concrete curing and the cement solidification of the PWR concentrated waste. The retarding effect increases with the increasing concentration of borate and results in a low waste loading and low volume efficiency of cement solidification. The HEST process, originally developed by Huang(1), differs from conventional cement solidification in the following characteristics.

1) The concentrated waste is solidified under a supersaturated concentration of borate, with a boron concentration of as high as 130,000 ppm.
2) The solidification reaction is relatively fast even when the boron content is as high as 130,000 ppm; the setting time is about 40 minutes.
3) The temperature built up in the solidified waste form is lower than that in cement solidification; the peak temperature in the curing of a 200L waste form is as low as 90^{o}C.
4) The dosage of cement used in this system is less than for conventional cement solidification. The solidification agent in the solidified product is in the range of 0.25 to 0.3 by weight.
5) The waste loading of the solidified product is much higher than that of conventional cement solidification, i.e. the dry-base waste (borate) in the solidified product typically exceeds 50wt%.

Besides these advantageous differences, the HEST process is simple and similar to the conventional cement solidification process.

HEST SYSTEM OUTLINE

An outline of the HEST system is shown in Fig.2. It consists of two subsystems, super-concentration and solidification subsystems. The super concentrated liquid is transferred to drums and mixed with cement using an in-drum mixer. The dual axis rotor unit is developed to prevent turbulence while keeping efficient mixing capability.

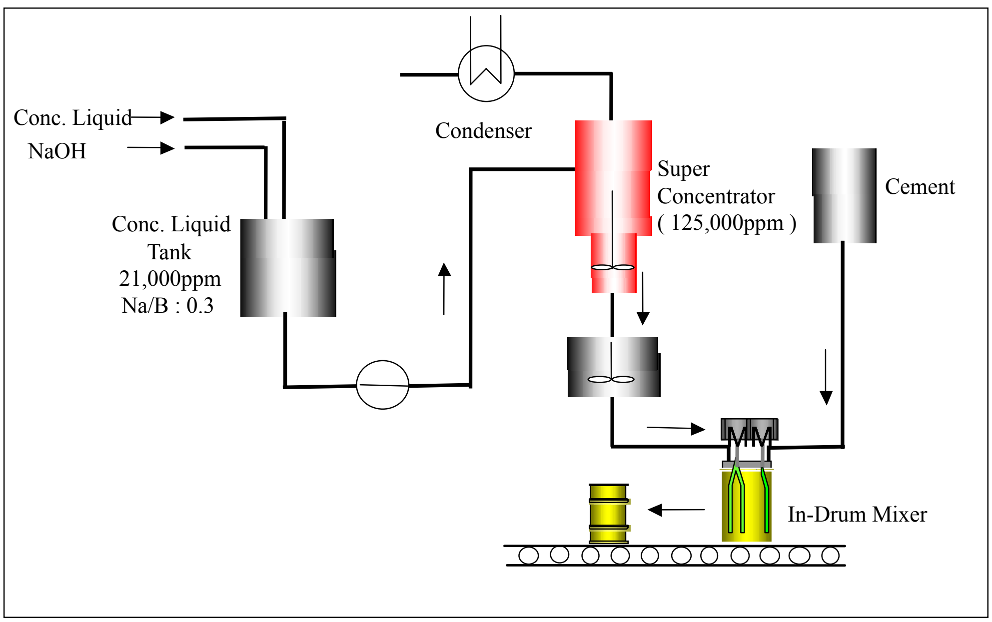

Fig.2: Outline of HEST System

The Super-concentration Subsystem

The concentrated liquid waste (Boron concentration: 21,000 ppm) is pretreated for Na/B ratio of about 0.3. The super- concentration subsystem is operated under vacuum to concentrate the waste solution of low borates concentration to a supersaturated state, up to 125,000 ppm B. An internal agitator is also provided for forced circulation of the solution. For better control of the boron content and getting a high concentration ratio of the product solution to the feed solution, a batch-wise operation is used.

The Solidification Subsystem

The super concentrated liquid is transferred to drums and mixed with cement using an in-drum mixer. The dual axis rotor unit is developed to prevent turbulence while keeping efficient mixing capability. The mixer is equipped with a frame-type stirrer and a diffuser-type stirrer which are used to mix the cement powder and the super concentrated liquid waste. The stirrers, driven by a pair of planetary shafts, rotate about their own axes with different speeds. The in-drum mixer is provided with a hood, with an air-tight connection to prevent any possible leakage of the materials from the drum during mixing. A spray nozzle set is installed to wash the stirrers and the interior of the hood with hot water after use. This washed water is returned to the super-concentration subsystem and mixed with the original liquid waste. Therefore there is no secondary waste generated in the HEST system.

PILOT PLANT TEST

A full scale pilot plant, with a treatment capacity of 50 l/h for the super-concentration subsystem and 200-l drum/batch for the solidification subsystem, was constructed. Fig.3 shows a typical concentrating profile to produce 200-l drum waste. It took about 25 hours to obtain 170L of super-concentrate (125,000 ppm B). A constant evaporation rate of 50 l/h was obtained without crystallization. The in-drum mixer provided a good mixing of the waste and the cement powder with a stirring speed of 1,500 rpm for the diffuser type stirrer. Due to the viscous property of the waste blending, the cleaning sequence took 20 min. Hot water was shown to be the best for cleaning the stirrers and the hood.

Table 1 summarizes the volume reduction efficiency compared with ordinary bitumen solidification process. Boron content was 30 kg/drum in HEST, while it was 12-16 kg/drum for bitumen. The volume reduction efficiency was as high as 2.5 compared to bitumen. The waste form characteristics were examined and some results are summarized in Table 2. Compressive strength and Kd values were higher than the disposal criteria for the Rokkasho Disposal Site.

CONCLUSIONS

The advanced liquid waste treatment system using HEST process was developed for PWR concentrated waste. Super-concentration of the waste solution was successfully achieved without the usual crystallization problem presented by borate. The in-drum mixer with dual stirrers in solidification subsystem gives excellent mixing of the waste solution and the cement. The stirrers were washed effectively with hot water. The waste form characteristics such as compressive strength met final disposal criteria. The detailed design is now being carried out for a new power station in Japan.

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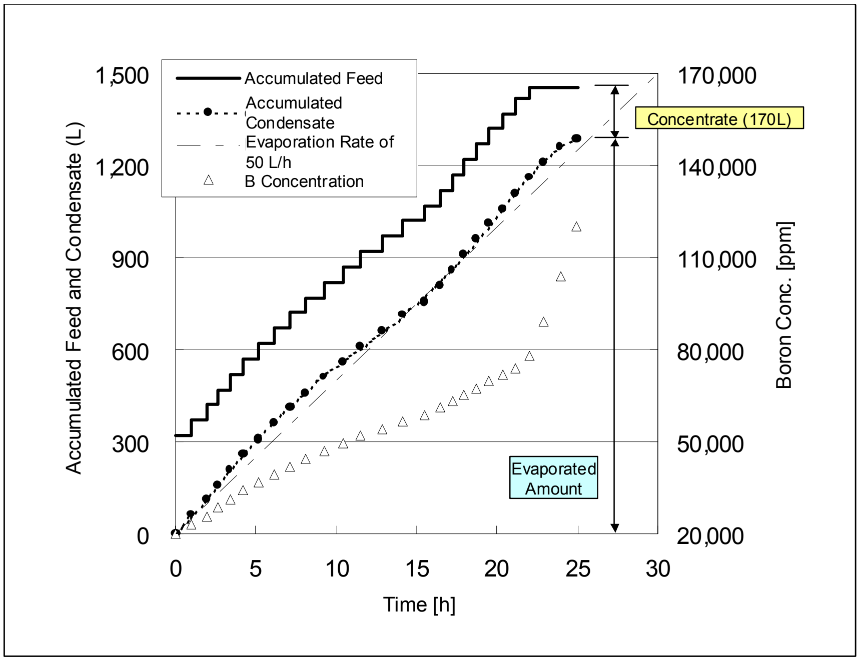

Fig.3: Pilot Plant Test Result - Concentrating Profile -

Table 1: Volume Reduction Efficiency Comparison

No.	Item	HEST	Bitumen
1	B Conc.	125,000ppm	21,000ppm
2	Amount of Waste	$15m^3$/year ↓ $1.8m^3$/year	$15m^3$/year
3	B Loading (kg/Drum)	30	12□16
4	Volume Reduction	1/2□1/2.5	1
5	Solidified Waste	11 Drums/year	24□30 Drums/year

Table 2: Waste Form Characteristics

		Disposal Criteria for Cement Package	HEST Package
Compressive Strength		> 1.5MPa	> 30MPa
Bleeding Water		Non	Non
Kd* (mL/g)	Cs	> 3	20 – 30
	Sr	> 30	50 – 480
	Ni	> 300	5100 – 7700