Commissioning Tests of the Ulchin LLW Vitrification Facility In Korea - 9107

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ABSTRACT

Since 1994, Korea Hydro and Nuclear Power Co., Ltd. (KHNP) has, together with SGN in France and Hyundai ROTEM, investigated and developed a vitrification process using a Cold Crucible Induction Melter (CCIM) to treat low-and intermediate-level radioactive waste. A commercialization project was launched in 2002 as a governmental nuclear power technology development project. The installation of the first commercial plant, Ulchin Vitrification Facility (UVF), was completed in 2007 inside Ulchin nuclear power plants # 5&6. Combustible dry active waste and low-level ion exchange resin will be treated in the UVF. The UVF has a waste feeding capacity of 20 kg/h and consists of waste pretreatment and feeding systems, a cold crucible induction melter (CCIM) system, an off-gas treatement system, a dust recycling system, as well as other systems. In order to assure that systems and equipments meet their design objectives and that the UVF complies with applicable regulations, equipment tests, system functional tests and inactive performance tests were conducted. Furthermore, a long-term inactive test was carried out for 202 hours to evaluate the overall performance and stability of the facility. During the test, about 1,700 kg of surrogate waste was vitrified and 302 kg of waste glass was poured into a glass mould. As the gaseous emission from the UVF was one of the key issues for the operational license and public acceptance, 25 hazardous gases and dusts were analyzed. The compressive strength of the waste glasses was also measured. Results showed that effluent concentrations of the off-gases and the quality of the waste glass met the regulatory limits with sufficient margins. Operation procedures of the UVF were revised based on experiences gained from the tests. By demonstrating satisfactory performance of the UVF, KHNP acquired an operational license in October, 2008 as an amendment to the operational license of the Ulchin NPPs. We are planning to conduct a simulated radioactive test to finally verify the safety of the UVF from a radiological point of view, and commercial operation of the UVF will be followed.

INTRODUCTION

In the early 1990s, KHNP considered vitrification technology as a prospective candidate for the treatment of low-and intermediate-level radioactive waste (LILW) generated from nuclear power plants. From 1994 to 1995, a study was performed to assess the feasibility of several melter technologies from technical and economic points of view. From the study, a cold crucible process was selected for use as a Korean vitrification process. In September 1999, a pilot scale vitrification facility was constructed at the Nuclear Engineering and Technology Institute (NETEC) of KHNP. Since then approximately 100 pilot tests have been conducted to evaluate the performance of the vitrification process and to obtain basic data for the design of a commercial facility.

A commercialization project, called the Ulchin Vitrification Facility (UVF) project, was launched in 2002 as a governmental nuclear power technology development project. Hyundai ROTEM participated in this project as a prime contractor. About 37 overseas and domestic companies including SGN, the Korea Power Engineering Company, and Hyundai Engineering Co., Ltd. joined as subcontractors. NETEC has been managing the overall project.

Low-level combustible radioactive wastes generated from Ulchin nuclear power plants # 5&6 will be treated in the UVF. With the exception of some systems, the UVF was installed inside the Radioactive Waste Building. Its designed feeding capacity is 20 kg/h for combustible dry active waste.

Some important milestones of the project were as follows:

- End of design : April, 2005
- Application of operational license : June, 2005
- Start of construction : June, 2006
- Completion of construction : December, 2007
- Completion of commissioning tests : May, 2008
- Acquirement of operational license : October, 2008

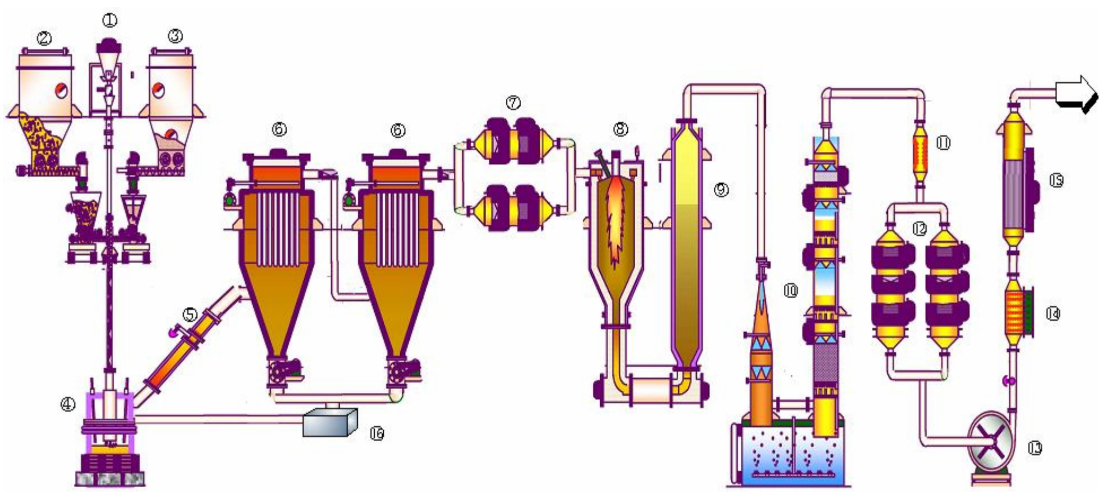
This paper summarizes the design characteristics of the UVF and the results of the commissioning tests, with a focus on the long-term inactive test.

DESIGN CHARACTERISTICS OF THE UVF [1]

The UVF process consists of a CCIM, an off-gas treatment system, a feeding system, utility supply systems, and several auxiliary systems. In the CCIM, wastes are burnt on the molten glass bath surface and the oxidized mineral components are incorporated into the molten glass. The produced glass is poured into a mould and the off-gas generated from the waste combustion process is cleaned in the off-gas treatment system.

The equipments exposed to relatively high radioactivity, such as the CCIM and a series of high temperature filters (HTFs), as well as drum handling equipment are installed in shielded cells, where access is prohibited during normal operation. Utilities such as the cooling tower, chiller, oxygen and nitrogen tanks, reagent chemical supply system, etc. are placed outside of the building.

The target waste streams for the UVF are combustible dry active wastes (DAWs) and W1 waste (a mixture of DAW and spent ion exchange resin with a mixing ratio of 5 to 1). The DAW typically consists of clothes, socks, gloves, shoe covers, paper, plastic bags, bottles, rubber gloves, etc.
The off-gas generated from the CCIM contains dust, volatile radioactive nuclides, acid gases (SOx, NOx, HCl, etc), and incomplete combustion products (CO, CxHy, etc). They are removed and/or decomposed upon passing through off-gas treatment equipments such as filters, scrubbers, and a de-NOx reactor. A simplified arrangement of the process is presented in Fig. 1.



(1) Glass Frit Feeder	(6) High Temperature Filter	(11) Reheater A
(2) DAW Feeder	(7) HEPA Filter	(12) Activated Carbon/HEPA Filter
(3) Resin Feeder	(8) Post Combustion Chamber	(13) Extraction Fan
(4) CCIM	(9) Off-Gas Cooler	(14) Reheater B
(5) Pipe Cooler	(10) Scrubber	(15) DeNOx System
		(16) Dust Recycling System

Fig. 1. A schematic diagram of the main UVF process

For the UVF design, process decontamination factors (DFs) were determined based on the results of pilot tests, which were performed with simulated Co-and Cs-loaded wastes. Although the dust removal efficiency of each High Temperature Filter (HTF) is 99.9%, the DF of one HTF was not considered in the design. In addition, the efficiency of the HEPA filter was assumed to be only 99% for the design margin.

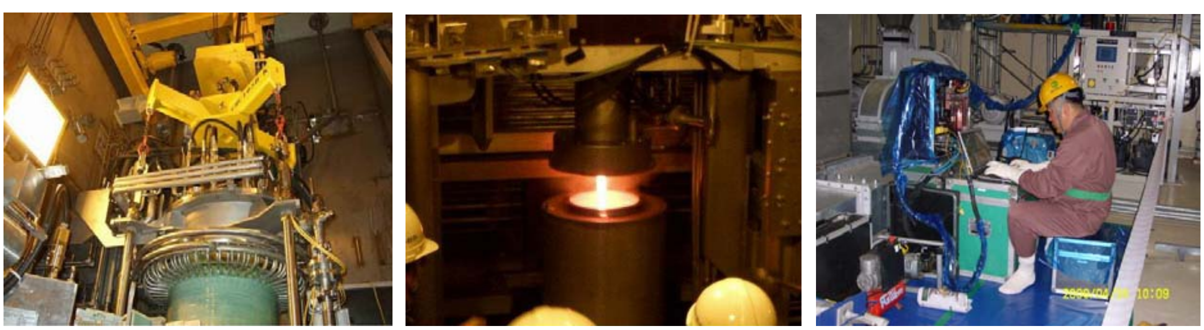
COMMISSIONING TESTS

Test Program

Commissioning tests were carried out in three phases: equipment tests, system functional tests, and inactive performance tests. About 2,300 equipments were examined and tested to check whether they were installed and operated properly according to their technical specifications and drawings. The UVF process was divided into 28 systems and the functions of each system were tested according to the respective test procedures. Filter leak tests and interlock tests were included in this test phase.

After ensuring that each part of the UVF met the designed conditions, a series of UVF operation tests were followed: blank tests, glass melting tests, remote maintenance tests, and inactive waste vitrification tests. Blank tests was conducted to check and adjust the main operation parameters, such as frequency, voltage and current, of the high frequency generator (HFG) and to confirm the insulation status of the CCIM and HFG. As a next step, glass melting tests were planned to check the overall performance of the melting system and the related utilities. Remote maintenance test included disconnecting or removing works for the following CCIM-connected equipments using two sets of manipulators: camera, cable, thermocouples, level detector, and waste feeding line and so on. The maintenance work for the case of CCIM replacement was also demonstrated.

Among them, a long-term inactive test was designed to assure that the performance of the UVF conforms to the applicable regulations as well as the design target of the UVF, especially with regard to the waste volume reduction factor, waste glass quality, and effluent emission concentrations. During the long-term inactive test, the overall performance of the UVF was evaluated.



(a) (b) (c)

Fig. 2. Photos of the commissioning tests

(a) CCIM remote maintenance test, (b) Glass melting and pouring test, (c) Hazardous gas sampling during the long-term inactive test

Operational conditions of the long-term inactive test

The test was conducted using surrogate W1 waste. In order to verify the efficiency of the HTF, non-radioactive isotopes of Co and Fe were loaded to the ion exchange resin. Waste and glass frit were continuously fed to the melter with rates of 18 kg/h and 1.5 kg/h, respectively. The waste glass was poured from the bottom of the CCIM after every 6 hours of waste treatment. Glass temperature in the upper part of the molten bath was maintained at around 1,150℃. Oxygen was supplied into the CCIM from the upper combustion part and from the bottom part of the molten glass. In order to evaluate the efficiency of the off-gas treatment system, 25 hazardous gases and dusts were sampled from the stack and their emission concentrations were analyzed. Gas sampling time was adjusted between 20 minutes and 4 hours. In addition, dust in the off-gases was sampled from the inlet and outlet of the first HTF to verify the decontamination factors for Co and Fe. Waste glass was also sampled from the mould after the test to measure its compressive strength. The license review organization, Korea Institute of Nuclear Safety, reviewed the test plan and procedures and inspected the test process.

Test Results

The UVF was operated safely over 200 hours, and then stopped after acquiring all samples and data as planned. Approximately 1,700 kg of waste was treated and 302 kg of waste glass was produced. As shown in Table 1, it was found that gaseous emission concentrations from the UVF meet both the regulatory limits and the design targets with sufficient margins. In the case of dioxins, the emitted concentration was only 0.2% of the design target. Also, 16 among 25 materials were found to be released at levels lower than their detection limits.

Analysis results of Co and Fe concentrations in dust samples showed that dust removal efficiencies of the first HTF exceeded 99.9% for both Co and Fe elements. Considering that the designed efficiency for the two sets of HTFs is 99.9%, these results indicate that the HTF systems have a sufficient safety margin.

The compressive strengths of the waste glasses were measured to be more than 100 times of the disposal criteria for cemented waste (500psi), which proved excellent mechanical durability of the waste glass.

Waste volume reduction factor was calculated from the waste feeding amount and glass pouring amount. About 40 kg of glass frit intentionally added for re-melting during the test was subtracted from the glass pouring amount for the volume reduction calculation. Densities of DAW, resin, and waste glass were assumed to be 0.2, 0.68 and 2.67 g/cm^3, respectively. The resultant volume reduction factor was approximately 76.

Table 1. Emission concentrations of hazardous materials from the UVF

Material	Regulatory limit*	Design target	Analyzed value
CO (ppm)	300	50	< 50
NOx (ppm)	150	100	< 100
SOx (ppm)	100	50	< 50
HCl (ppm)	50	40	< 40
Dust (mg/Sm^3)	100	50	< 50
Dioxins ($ng\text{-}TEQ/Sm^3$)	5	0.5	<< 0.5
NH_3 (ppm)	100	100	< 100
F compounds	10	10	< 10
Cl_2	3	3	< 3
Other 16 materials	(Different for each material)	Same as the regulatory limits	Not Detected

* Regulatory limit for waste incinerators with a capacity below 200 kg/h

CONCLUSION

The commissioning test program of the UVF was completed successfully in May 2008. Test results showed that the performance of the UVF met the technical specifications and regulations. In particular, the performance of off-gases treatment and the quality of the waste glass verified that the UVF could be operated in a very safe mode with respect to the environment and public. Experiences and lessons learned from the commissioning tests were reflected in the UVF operation procedures.

By demonstrating the satisfactory performance of the UVF, KHNP acquired an operational license for the UVF on October 8, 2008. The UVF is expected to commence commercial operation and vitrify radioactive waste generated from Ulchin NPPs in 2009. It is expected that the UVF will not only enhance the safety of the waste disposal repository, but will also greatly contribute to the further promotion of the Korean nuclear power generation program.

ACKNOWLEDGEMENT

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REFERENCES

[1] Byoung-Chul Park, et al., “Development and design characteristics of the vitrification facility for DAW and low-activity ion exchange resin generated from NPPs”, WM’07, February 25-March 1, 2007.

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