Development of Concentrated Waste Drying Treatment System Designed to be Mobile and Compact for Radioactive Liquid Waste Treatment in NPPs

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1. Introduction

The Liquid Radwaste System(LRS) of the Nuclear Power Plants(NPPs) is treated using Liquid Waste Evaporator and Concentrated Waste Drying System (CWDS), or Centrifuges and LRDPS(Liquid Radwaste Demineralization Processing System), MF(Micro Filtration) and RO(Reverse Osmosis Membrane). The Hanul #5,6 uses Centrifuges/MF-RO and LRDPS, and due to the deterioration of LRDPS performance, it is necessary to introduce the CWDS, but, due to the limited space operating conditions, it is difficult to introduce existing facilities(37 m^3 or higher) used by other NPPs.

Therefore, in this study, we developed mobile/ compact Drying Treatment System(DTS), which has the same drying performance as existing facilities and has a size of about 1/3(15 m^3 or less). It is designed to be usable in a limited spaces and mobile.

2. Methods and Results

The design, manufacture and performance of the concentrated waste Drying Treatment System(DTS) developed in this study were evaluated.

2.1 Status of Domestic Drying Treatment Facility

The Concentrated Waste Drying System(CWDS) used in the existing NPPs operate CWDS supplied by Vectra Technology Co., Ltd., Concentrate Treatment System(CTS) supplied by Energy Solution Diversification Service Co., Ltd. and etc. It has a size of 37.44 ~ 65.91 m^3 and a horizontal type. Also, the size of the critical accident liquid waste treatment facility developed and operated by KHNP Central Research Institute(CRI) is 49.90 m^3, which is a modular mobile facility and is of a vertical type.

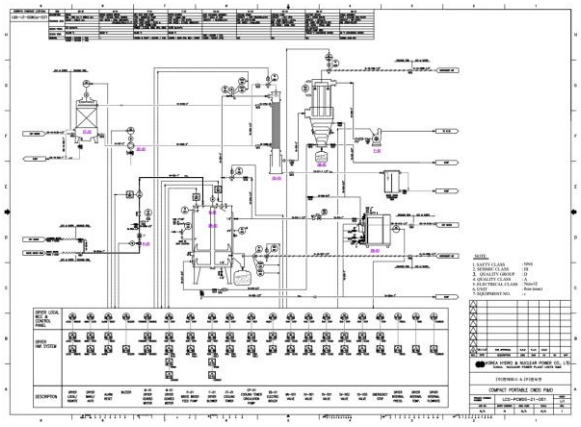
There have been cases in which nuclear-related laboratories or NPPs have been developed and operated as a modular type in the form of a skid-mount to temporarily treat highly radioactive liquid waste stored for a long period of time. But, there is no case of being developed as a mobile type and compacted design such as this system, and the currently used facility is larger, so it cannot be installed in areas with limited space.

2.2 Design and Manufacturing of Drying Treatment System(DTS)

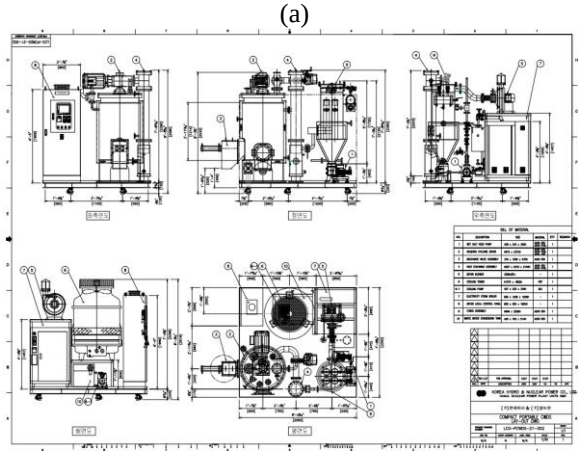
2.2.1 Design of DTS

This systems was designed in consideration of domestic standards such as KEPIC NWB 2000, 4000, 5000[1,2,3] and NSSC(Nuclear Safety And Security Commission) Notice, as well as overseas standards such as ANSI/ANS-40.37(2009)[4] and US light water reactor standards, ANS-55.1-1992;R2000[5] etc.

Technical criteria for devices such as pressure vessel, piping, valves and pumps was applied centrifugal film evaporator facilities using piping size, instrument control requirements, controls and instrument mechanical devices in NWB 2000(Technical criteria for solid radioactive waste treatment equipment) and ANSI/ANS -40.37(Equipment codes). In addition, parts in direct contact with liquid waste, such as piping etc., are designed to prevent corrosion using KEPIC-MDF type 304 or 316 stainless steel.



(a)



(b)

Fig. 1. Design drawing of DTS ; (a) P&ID, (b) Lay-out

2.2.2 Manufacturing of DTS

Main plate and pipe, which are materials for DTS, were ordered with STS 316L and 304 material, which is suitable for ASTM standards, and checked the material report. Also, when manufacturing parts, the test report of the parts manufactured after the witness inspection was reviewed to confirm compliance with the specifications.

Radiography Testing(RT) and Liquid Penetrant Testing(PT) were performed on the welds during manufacturing, and pressure vessel was tested for hydraulic pressure and water filling, and were confirmed by the authorized inspection agency.

The developed mobile/compact concentrated waste DTS is a thin-film decompression vacuum drying device for concentrated waste using cyclone and is dried using a steam boiler of 150 kW(steam evaporation 200 kg/h).

The heater of the steam boiler consists of two 30 kW and two 45 kW, which are four breakers, and can be used by selecting from 30 kW to up to 150 kW depending on the electricity and liquid waste volume in the area used.

The size of this system is about 15 m^3 compact, and it is manufactured to treatment 500 L or more of concentrated waste per day(8 hours).

Fig. 2. Acceptance and visual inspection

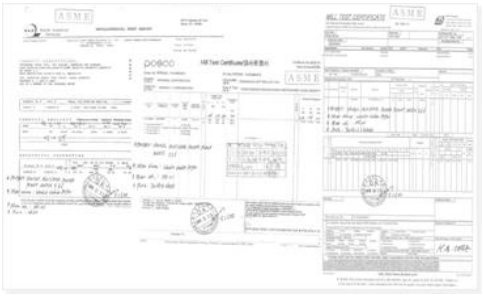
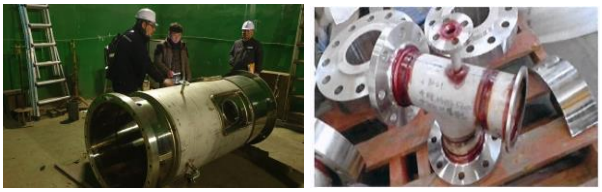
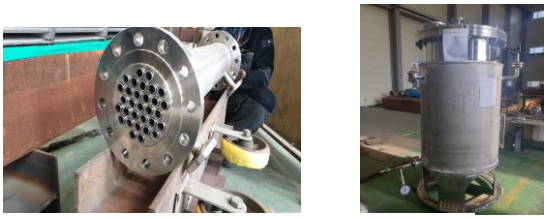


Fig. 3. Certification of materials



(a) (b)

Fig. 4. NDT(Non-destructive testing) ; (a) RT, (b) PT



(a) (b)

Fig. 5. Manufacturing inspection ; (a) Indirectness condenser, (b) Hydraulic pressure & water filling Test

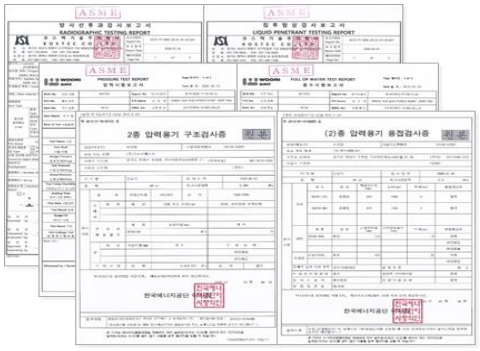


Fig. 6. Certification for each test

Fig. 7. Drying facility of centrifugal thin-film type

2.3 Performance Testing of Drying Treatment System(DTS)

2.3.1 Temporary Performance Testing

The mobile/compact concentrated waste DTS was manufactured and after no-load test, the performance test was carried out using water.

As a result of drying tests of 65 L and 100 L of water, drying was completed in 46 minutes for 65 L and about 50 minutes for 100 L. Therefore, as a result of the test using water, since the drying performance is good, the performance test of the DTS was carried out by manufacturing a simulation specimen of the concentrated waste of the NPPs.

2.3.2 Component and Manufacturing of Simulation Specimen

The weight of 12 compounds according to the boron concentration of each concentrated waste was calculated such as Table 1, using the results of the

analysis of the dried powder of the concentrated waste on the NPPs[6]. And a simulation specimen was prepared by dissolving the compound in water.

As for the simulation specimens, since the boron concentration of the NPPs concentrate was at least 1,900 to 30,000 ppm, 4 types of boron concentrations of 1,900 ppm, 10,000 ppm, 20,000 ppm, and 30,000 ppm were prepared and used as the simulation specimens. And the performance test was conducted by manufacturing 85 L each to verify the satisfaction of the target performance of the concentrated waste DTS of 500 L/day.

Table I: Weight by Element of Simulation Specimen (85 L Base)

Reagent		Solute Weight (g)			
		1,900 ppm	10,000 ppm	20,000 ppm	30,000 ppm
H_3BO_3	B	923.7	4861.7	9723.5	14585.2
NaOH	Na	109.3	575.5	1150.9	1726.2
KOH	K	2.8	14.6	29.1	43.7
$CaCl_2$	Ca	3.7	19.3	38.6	57.8
$ZnCl_2$	Zn	1.0	5.3	10.6	15.9
$MgCl_2 \cdot 6H_2O$	Mg	3.4	18.0	36.0	54.2
SiO_2	Si	0.7	3.6	7.3	10.9
$Fe_2O_3 \cdot 7H_2O$	Fe	0.9	5.0	10.0	14.9
LiCl	Li	0.6	3.4	6.7	10.1
$AlCl_3 \cdot 6H_2O$	Al	0.6	3.0	6.0	9.0
$MnCl_2 \cdot 4H_2O$	Mn	0.1	0.6	1.2	1.8
NiO	Ni	0.04	0.2	0.4	0.6
합계		1046.8	5510.2	11020.3	16530.3

2.3.3 System of DTS

The operation of concentrated waste DTS can be operated on the on-site control panel and the remote control panel, and it was systematized to control everything through the computer's HMI screen. And the drying conditions were configured to set the conditions to be used, such as input amount of liquid waste, input time, number of inputs, and drying time on the liquid waste setting screen.

The heater capacity is selected from the steam boiler, and when all settings are completed, the drying system is configured to operate when the start button is clicked on the HMI screen.

This system can be operated automatically and manually, automatically shut down in case of abnormal conditions, and all systems can be shut down with the Emergency Stop button.

(a) (b) (c)

Fig. 8. Drying Treatment System(DTS) ; a) On-site Control Panel, b) Remote control Panel, c) HMI Screen

2.3.4 Result of Performance Testing

As a result of preparing 85 L of a simulation specimens of concentrated waste and performing a drying test, drying was completed in about 50 minutes.

After measuring the dried powder with FE-SEM(Field Emission Scanning Electron Microscope), it is confirmed that it is a fine powder(up to 162 μm). In addition, to check the target performance of the concentrated waste DTS(500 L/day, 8 hr), as a result of six consecutive dry runs of 85 L, 510 L was dried in about 5 hours for all concentrated waste simulation specimens.

The moisture rate of dried powder was 1.8 to 2.7%, which is very lower than the target of 10%, and the drying condition was very good.

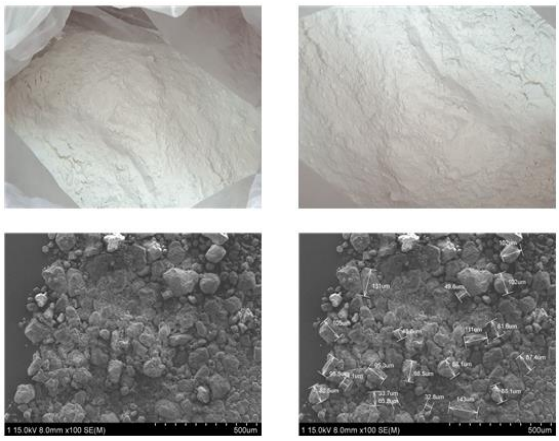


Fig. 9. Form of dried powder and measurement result of powder in FE-SEM

Table II: Measurement Results for Moisture Content (Amount: 510 L)

Boron Concentration(ppm)	Drying Time(min)	Moisture Content(%)
1,900	300	2.2 ~ 2.7
10,000	300	1.9 ~ 2.4
20,000	300	2.1 ~ 2.5
30,000	300	1.8 ~ 2.2

2.4 On-site Verification Test of Drying Treatment System(DTS)

The on-site verification test of DTS was conducted twice after completing the performance test.

The first on-site verification test was to drying 500 L of concentrated waste with a boron concentration of 30,000 ppm within 8 hours, and as a result of the test was conducted using 150 kW of steam boiler power and completed drying in 5 hours. And, The moisture content of the dried powder was excellent at 2.5%.

The second on-site verification test was conducted to dry 300 L of Hanul #5,6 concentrated waste(boron concentration 1,900 ppm) at within 8 hours using 45 kW considering the amount of electricity, and as a result of the test was completed in 7.5 hours. The

moisture content of the dried powder was very good at 2.4%.

3. Conclusions

In this study, concentrated waste Drying Treatment System(DTS) of centrifugal thin-film drying method developed for the first was manufactured in accordance with domestic and foreign technical standards and performance test was conducted.

As a result of the test, 500 L of the concentrated waste simulation specimens was dried in 5 hours, less than the target performance of 8 hours, and the moisture rate of dried powder is less than 2.7% fine powder, and we confirm that the DTS performance is very good.

The on-site verification test was conducted twice for the simulation specimens of concentrated waste and for the concentrated waste of NPPs and the results of the test were very satisfactory result.

The drying performance of the concentrated waste DTS developed in this study is the same as that of the existing facilities, and the size of the DTS is a mobile/compact system that is about 1/3 of the existing facilities. Therefore, since it can be used even in areas where space is limit, it can be used as an alternative to existing aging the CWDS, and it can be used when NPPs decommissioning.

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