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A Study on Treatment of Concentrated Radwaste Water in NPPs

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1. Introduction

The LRS(Liquid Radwaste System) of the NPP consists of "Liquid Waste Evaporator and CWDS (Concentrated Waste Drying System)" or "RO(Reverse Osmosis Membrane) & LRDPS(Liquid Radwaste Demineralization Processing System)".

Due to insufficient ability to remove radioactive and conductive materials from LRS, additional MF(Micro Filtration) and RO facilities were introduced, but liquid radioactive wastes are stored in drums because of deterioration of the demineralizer, the main treatment facility. Although many NPPs in Korea are adapting the CTS(Concentrate Treatment System) for drying CLW(concentrated nuclear liquid wastes) and polymer-adding solidifying, the particle size of dried powder is not suitable for domestic disposal admission standards(1 to 13mm), and the scattered powder can cause internal and external exposure by the workers' breathing. In this study, therefore, a portable/compact Centrifugal Thin-film Drying Facility(p-CTDF) was developed for treating CLW produced in NPPs.

This facility is believed to help reduce radiation exposure to workers and secure disposal safety.

2. Methods and Results

First of all, CLW treatment facilities in NPPs are investigated, and then the design & manufacture of drying facility(DF), fabrication of simulated dried specimen with DF, and the design & manufacture of p-CTDF, and its performance test result are described.

2.1 Domestic Drying Facilities(DF)

The drying facilities at the NPPs are listed in Table 1, are operating d-DFs of Vectra Technologies, Inc., Energy Solutions Diversified Services, Inc., and JS Chemical Co. The volume of DFs is 37.44 to 65.91㎥ and is of a horizontal type.

The volume of the critical accident waste liquid treatment facility developed and operated by KHNP Central Research Institute(CRI) is 49.90㎥, which is a modular mobile facility and is of vertical type.

The DF of CLW operated at the NPPs uses the auxiliary steam supplied from the plant. DF is indirectly heated with steam and granules on the dryers' inner wall are pulverized with a RSB(Ribon Screw Blender), but due to its large size, they cannot be installed at some NPPs with limited space.

The MVR(Mechanical Vapor Re-compression) type drying technology is capable of compact design, but MVR is expensive to manage and maintain, and the final residue cannot be dried as a solid, which requires a separate drying. Therefore, this study was carried out to develop a portable/compact dryer for treating CLW and the physical requirements of the dried CLWs can secure disposal safety.

Table 1. Current Status of DF for CLW at NPPs

Installation Place	Facility(Supply Co.)	
	Drying	Solidfication
Kori 1,2, Hanbit 1,2 & Hanul 1,2	Vectra Technologies, Inc. Model : RVR-800(CWDS)	
Shin -Kori 1	Energy Solutions Diversified Services, Inc.	Korea Nuclear Engineering. Co.
Shin -Kori 2	Energy Solutions Diversified Services, Inc.	JS Chemical. Co.
Wolsong 3	Energy Solutions Diversified Services, Inc.	Korea Nuclear Engineering. Co.
UAE BNPP 1,2	JS Chemical. Co.	
Shin -Hanul 1	JS Chemical. Co.	
CRI	Modular/Mobile Facility for Liquid Radioactive Waste Treatment	

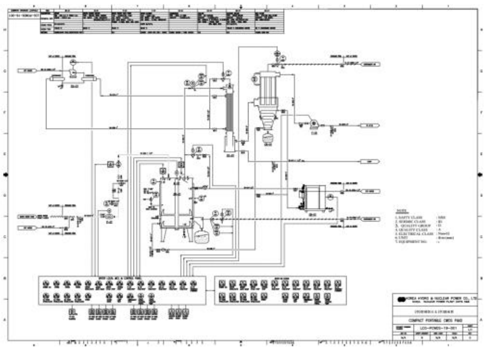
2.2 Manufacturing and Performance Test of DF

2.2.1 Design and Manufacturing

The domestic reference standards for Nuclear Safety And Security Commission(NSSC) Notice No.2017-60 and KEPIC NWB 2000,4000,5000 based on the contents of the ANSI/ANS 40,55 series etc. and the international reference standards such as ANSI/ANS-40.37(2009) 'Mobile Low-Level Radioactive Waste Processing System' and ANS-55.1-1992;R2000 'Solid Radioactive Waste Processing System for Light Water Cooled Reactor Plants' etc. were considered and reflected in the design and manufacture of DFs.

The devices such as container pressure, piping & valves and pumps are designed in accordance with the Technical standard of NWB 2000 and ANSI/ANS–40.37 Equipment Codes.

For piping, KEPIC-MDF type 304 or 316 stainless steel(or suitable corrosion resistant material) was used, in accordance with the piping specifications (NWB 2000 and ANSI/ANS-40.37), the inside diameter of the piping is less than 3/4 inches and less than 2 1/2 inches and the inside diameter of the piping is at least 1 1/2 inches when transporting slurry. In addition, conditions of instrumentation and control are applied in p-CTDF using mechanical device of NWB 2000 and ventilation or discharge valves are designed in accordance with ANSI/ANS-40.37.


(a)

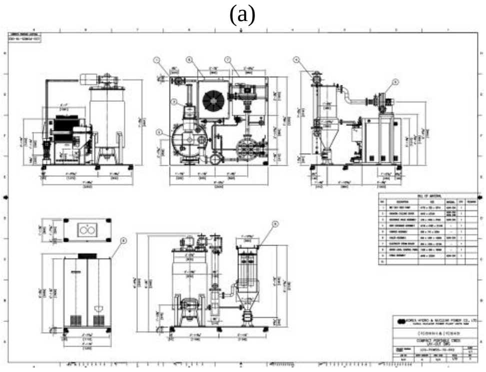

(b)

Fig. 1. Design Drawing (P&ID / LAY-OUT)

Fig. 2. Drying Facility of Centrifugal Thin-Film Type

The p-CTDF developed is a device that uses cyclone to dry thin films of concentrated waste solution, which is smaller than 15m^3 in size and can handle 500L/Day (8 hours).

2.2.2 Performance Testing

a) Fabrication of Simulation Specimen

Based on the results of the KHNP prior study(Feasibility Study for the Glassification of Boric Acid Concentrated Waste, 2009 Analysis of the Components of CLW), the simulation specimen of CLW was concentrated in the L-TVC(low-temperature vacuum concentrator) and then performance of p-CTDF was tested.

Table 2. Weight by Element of Simulation Specimen(1L base)

Reagent	Element	Content (ppm)	Solute Weight (g)
H_3BO_3	B	195333	1117.2469
$NaOH$	Na	76000	132.2314
KOH	K	2333	3.3481158
$CaCl_2$	Ca	1600	4.4305604
$ZnCl_2$	Zn	583	1.2152759
$MgCl_2$	Mg	495	1.9390843
SiO_2	Si	391	0.8364351
Fe_2O_3 $7H_2O$	Fe	230	1.1766264
$LiOH$	Li	127	0.4382781
$AlCl_3$ $6H_2O$	Al	77	0.6889819
$MnCl_2$ $4H_2O$	Mn	38	0.1368465
$NiCl_2$ $6H_2O$	Ni	35	0.1416858

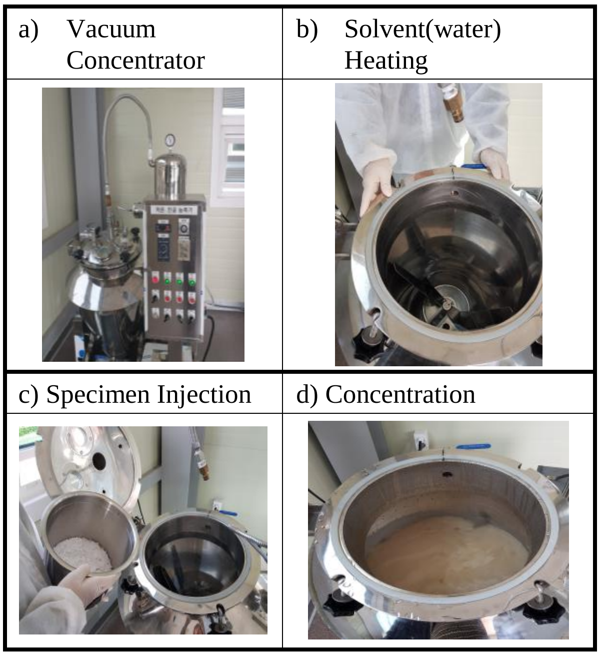


Fig. 3. Process of L-TVC

b) Drying of a Simulation Specimen

The result of using L-TVC to concentrate the simulation sample of CLW solution and drying it for one to two hours using p-CTDF developed was that the moisture content was dried in the form of fine powder of not more than 10%.

Fig. 4. Drying of Simulating Specimen

Measurement of boron content of powder dried in the developed p-CPDF by using ICP-OES(Inductively Coupled Plasma-Optical Emission Spectrometry) indicates that boron content difference was about 2.6% compared to the analysis results of the CLW at the NPPs. The average size of the simulation specimen powder was observed up to 162μm in measured using FE-SEM(Field Emission Scanning Electron Microscope).

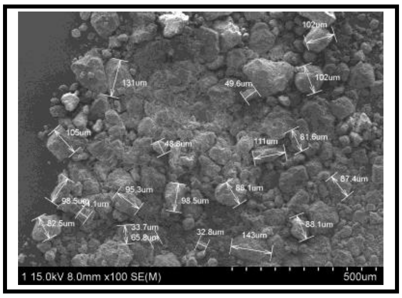


Fig. 5. Size of Drying Powder

c) Measurement of the moisture content for the drying powder

The moisture content of the dried powder was measured by the moisture meter (BEL, I-THERMO) at 2.65 to 7.81 %, three times lower than the moisture content of dry powder (approximately 8 to 18 %) with the conventional concentration waste dryer (CWDS).

Table 3. Measurement Results for Moisture Content

Drying Time	Start Weight(g)	End Weight(g)	Moisture Content(%)
1hr	3.505	3.231	7.81
1hr 15m	3.504	3.251	7.22
1hr 30m	3.494	3.274	6.28
1hr 45m	3.514	3.325	5.38
2hr	3.488	3.396	2.65

2.3 Fabrication of CF(Compression Forming)

The physical(structural) characteristics for disposal of radioactive wastes shall be treated and packaged in such a way that particles less than 0.01 mm in diameter of the waste are non-dispersive if they comprise more than 1% of the weight of the waste or less than 0.2 mm in diameter of if they comprise more than 15%.

Methods for treating dry powder include wet and dry granulation, injection, and tablet. In this study, the CF(compression forming) facilities of tablet-type were used because they were manufactured with a certain size and weight, easy to store, wide range of pressure to use, widely used in industrial and medical fields, and quality guaranteed.

Problems such as capping, stitching, and lamination were caused with commercial CF, therefore, in this study, the upper and lower punch of developed CF was coated DLC(Diamond Like Carbon), and the die was also coated with DLC after tapping on the Super-hard die. The test results showed that the shape of pellet was good. Also, the compressive strength of the CF was very good, at 23.7 to 35.7 kgf, which was higher than the paraffin solidified waste strength criterion. Therefore, it is judged that the non-dispersive required by the physical(structural) characteristic of radioactive waste disposal can be satisfied.

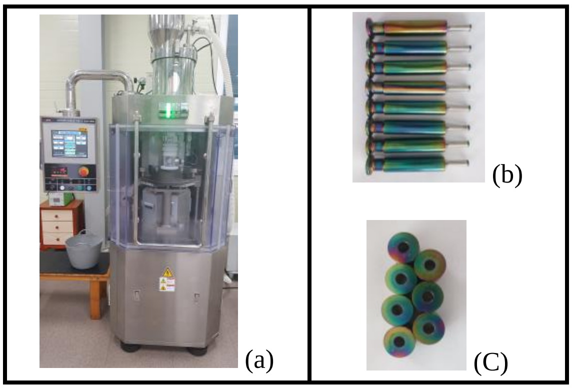


Fig. 6. (a) CF Facilities and (b) Punch / (c) Die

Table 4. Results for CF

Filling Depth (mm)	Main Pressure Position (Lower)(mm)	Pressure (kgf)	Thickness (mm)
14	7.0	500~600	6.0
13	7.0	500~650	6.0
12	7.0	800~1000	5.8
11	7.0	600~800	6.0
10	7.0	600~700	5.8
9.0	6.5	600~800	5.0
8.5	6.5	350~450	5.0

Fig. 7. Sample of CF

Table 5. The Results of Measuring Compressive strength for CF Sample

Filling Depth (mm)	Main Pressure Position (Lower)(mm)	Pressure (kgf)	Compressive Strength (kgf)
14	7.0	500~600	35.7
13	7.0	500~650	33.6
12	7.0	800~1000	31.2
11	7.0	600~800	31.2
10	7.0	600~700	27.6
9.0	6.5	600~800	23.7
8.5	6.5	350~450	22.8

3. Conclusions

The facility for treatment CLW was developed in consideration of domestic and international reference standards. Tests of performance on this facility showed that pellets contain 2.65 to 7.81 percent moisture content when dried for one to two hours, fine powder(av. size 162μm) was produced.

The results of compressing the dry powder of the simulation specimen in the CF Facilities, which is widely used in the industrial and medical fields, confirmed that the forming condition was good at 350 to 1,000 kgf pressure without causing any problems such as capping, stitching and lamination. In addition, the compressive strength of the CF was 23.7 to 35.7 kgf, which was higher than the paraffin solidification strength criterion, and the CF can produce very good pellets.

It is believed that if the CLW is dried using developed p-CTDF and the pellet is made in the CF, the disposal safety can be secured, and if treated in an automated process, it will contribute to reducing radiation exposure dose to the workers.

ACKNOWLEDGMENTS

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