Review of the Applicability of Plasma Treatment for Paraffin -Based Concentrated Waste Solids

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***Keywords** : Radioactive waste, Plasma processing technology, Paraffin,

1. Introduction

Various types and forms of radioactive waste are generated during the operation and decommissioning of nuclear power plants. "Radioactive waste" refers to radioactive materials or materials contaminated by them that are subject to disposal. Due to stricter disposal regulations, unclear acceptance criteria, and a lack of established treatment technologies, nuclear power plants have been storing large quantities of radioactive waste for extended periods. Concentrated liquid waste generated at these plants is typically stored or disposed of after solidification, with some managed as paraffin-based organic solids. However, paraffin, a saturated hydrocarbon with a high heating value, is highly flammable and poses fire risks and stability issues during long-term storage. In particular, solids with high organic content reduce volume efficiency during final disposal, acting as a burden on the management of low- and intermediate-level radioactive waste. Consequently, there is a growing need for high-temperature treatment technologies that can fundamentally remove organic matter and inorganize the waste. This study focuses on reviewing the applicability of plasma heat treatment as an alternative for the volume reduction and stabilization of paraffin solids.

2. Plasma Treatment Technology

Plasma treatment is a technology that utilizes electric arc phenomena, similar to lightning, to melt radioactive waste—such as metals, concrete, soil, and asbestos—at temperatures of approximately 1,600°C, reducing the volume to about 1/5 of the original size

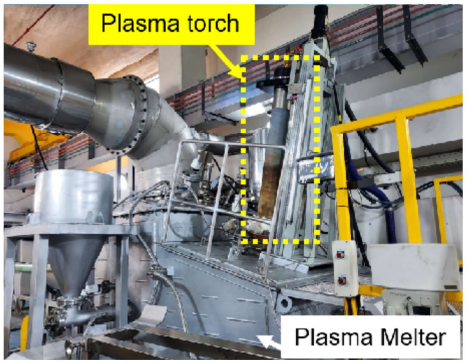

Fig. 1. MW Plasma System

3. Generation and Characteristics of Concentrated Liquid Waste Paraffin

Liquid waste from nuclear power plants contains significant amounts of boric acid. Currently, all nuclear plants treat liquid waste using the concept of evaporation and concentration. Boric acid-containing waste is a major byproduct of Pressurized Water Reactors (PWRs), containing approximately 5–12 wt% of boric acid. In the primary coolant of a PWR, boron exists at levels of 500–2,000 ppm. Boric acid waste is generated through regular maintenance, sampling, and leakage. Generally, this waste is treated via evaporation and concentration, and since 1996, it has been solidified into paraffin media using Concentrated Waste Drying Systems (CWDS).

Table 1. Composition Distribution of Concentrated Waste Dry Powder

Element	Content (ppm)	Oxide	Content (wt%)
B	195,333	B2O3	62.941
Na	76,000	Na2O	10.243
K	2,333	K2O	0.282
Ca	1,600	CaO	0.224
Zn	583	ZnO	0.073
Mg	495	MgO	0.082
Si	391	SiO2	0.084
Fe	230	Fe2O3	0.033
Li	127	Li2O	0.027
Al	77	Al2O3	0.015
Ni	38	NiO	0.005
Mn	35	MnO2	0.006
Co	<10	Organic Matter	-1.466
Cr	<10	H2O	-24.52
Cs	<10	-	-
TOC	6,262	-	-
Ignition loss	8,400	-	-
Total	291,905	SUM	100.00%

4. Results of Applicability Review for Mock-up Sample Preparation

Paraffin generally does not react with acids or bases and produces carbon dioxide (CO_2) and water (H_2O) upon oxidation. Its melting point ranges from approximately 47–65°C, and it produces soot during combustion. Before producing mock-up paraffin solids, the melting point of the paraffin was verified. Paraffin

actually used in nuclear power plants was obtained, and the melting temperature and time were confirmed using a water bath method

Table 2 Results of Paraffin Melting Point Test

Temp.(°C)	Time(min)	Melting State
11.3		
20	6	
30	5	
40	4	
50	5	
60	5	Melting starts at 55°C
65	5	
70	4	100% Melted
Total	34	

5. Results of Plasma Treatment Review for Paraffin Solids

Paraffin begins thermal decomposition in the 300–500°C range. Under ultra-high-temperature conditions, hydrocarbon bonds rapidly dissociate, converting the material into simple gaseous substances. Plasma heat treatment creates a reaction zone exceeding several thousand degrees, enabling the virtually complete decomposition of organic matter and the simultaneous melting of inorganic substances. Based on theoretical thermal behavior and literature-based reaction characteristics, organic components in paraffin solids are highly likely to decompose without residue in ultra-high-temperature environments, which is considered superior to conventional incineration processes in terms of organic removal efficiency.

Furthermore, inorganic salts and non-volatile radionuclides (Co, Sr) are likely to be stably captured within the molten slag matrix, potentially leading to long-term leach reduction effects. While the volatilization of certain radionuclides (Cs, etc.) is possible, it is deemed manageable within the scope of off-gas treatment facilities. From a mass balance perspective, a significant volume reduction effect is expected due to the removal of organic matter, and the inorganic material is expected to be converted into high-density slag, ensuring disposal stability.

6. Future Plans

Quantitative evaluations of nuclide distribution, slag leaching characteristics, and process energy consumption will be conducted through pilot-scale heat treatment tests using mock-up paraffin solids. Additionally, the technical feasibility will be established based on empirical data by verifying off-gas treatment efficiency and process safety, followed by a comprehensive applicability assessment including an economic analysis.

REFERENCES

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