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Melting Decontamination of the Aluminum Wastes generated from TRIGA MARK-Ⅲ Research Reactor in the Electric Arc Furnace

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1. Introduction

Recently, there has been growing interest in D & D (Decommissioning and decontamination) of the nuclear facilities around world. In Korea the TRIGA MARK Ⅲ research reactor has been dismantled since 1997. These decommissioning works result in the various metal wastes such as stainless steel, carbon steel, aluminum and copper. Since the total amount of the steel (stainless steel, carbon steel) wastes from nuclear facilities was up to 70 ~ 80%, considerable researches have been devoted to the radionclides distribution and decontamination characteristics of the steel until now. But based on the report by Garbay and Chapuis [1], they concluded that a PWR contained 20 to 100 ton of aluminum, mostly as electrical cable. Therefore rather more study has been paid to the characteristics of the aluminum melting and the distribution of radionuclides.

According to the review of the previous research, most studies have been focused on the melting characteristics of aluminum wastes contaminated with the uranium oxide. There were few investigations on the melting characteristics of the aluminum wastes contaminated with the cobalt and cesium. Grabener et al. [2] showed that the aluminum wastes with the cobalt and cesium were easily decontaminated by using the melting technology with flux agents. The main purpose of this study is to give the information about the melting decontamination of the aluminum wastes from TRIGA MARK Ⅲ research reactor.

The aluminum melting tests were conducted in the electric arc furnace equipped the graphite arc system. To increase the fluidity of the melt and prevent the aluminum melt from an oxidation, the 5wt% salt (flux agent) was added. The cobalt was removed from the aluminum ingot phase and transferred to the slag phase up to 75% by the slat melting process. The cesium was mostly eliminated from the aluminum ingot phase and transferred to the slag and dust phase. We found the similar trends of the nuclides distribution in air and the inert gas condition.

2. Experiment

The lab-scale graphite arc melting furnace was used to verify the melting performance of aluminum wastes with various operational conditions such as kinds of fluxes, weight of the added flux and the melting conditions. As shown in the Figure 1, the arc melting system consists of one graphite electrode and a copper crucible with a graphite refractory which serves as a counter electrode. The schematic The cooling water flows in the surroundings of the graphite arc electrode and the copper crucible. The input power was supplied by controlling the direct current voltage from the power supplier. The two types of aluminum specimens were used to evaluate the distribution of radionuclides. One was the aluminum specimens which were contaminated with the cobalt and cesium radioisotopes. The other was the aluminum wastes which come from TRIGA MARK Ⅲ research reactor in Seoul.

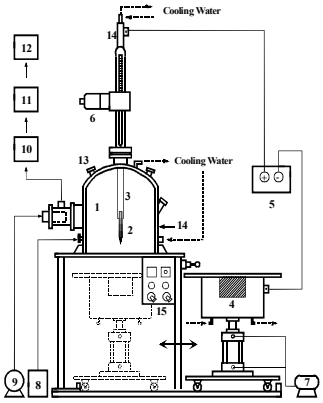

Figure 1. The schematic of the electric arc furnace.

As shown in the Table 1, the aluminum specimens were contaminated with the RI (Co-60, Cs-137) and then added with the flux. The mixture was melted under the argon atmosphere and the oxidation condition for 5 minutes. After completing the aluminum melting, a molten aluminum was cooled and solidified in the copper mold. The ingot samples were taken as chips by drilling of the ingot to the depth of about 10mm in two different locations. The slag was easily separated from the ingot. The ingot and slag samples were analyzed with the MCA (Multi Channel Analyzer).

Table 1. Operation condition of aluminum melting

Al specimen	A : Aluminum specimen (1x15x15mm) B : TRIGA Aluminum wastes (pipe, plate)
Radioisotope	A : Co-60 (50 ~ 163 Bq/g) B : Cs-137 (30 ~ 127 Bq/g)
Flux	Type A : NaCl(45),KCl(40), Na_3AlF_6(15) Type B : NaCl(45),KCl(40), KF(15)
	Added weight : 3, 5, 7, 9 wt%
Melting condition	A : Oxidation condition B : Inert gas condition

3. Results

The aluminum melting tests were performed using the aluminum specimen contaminated with the radioisotope

and the aluminum wastes from TRIGA MARK Ⅲ research reactor. The aluminum specimen used in this study was contaminated with contaminated with Co-60 and Cs-137(RI), because the aluminum wastes from the nuclear facilities were mainly contaminated with Co-60 and Cs-137. The aluminum melting was performed in the inert gas condition (Ar). The Co was removed and transferred to the slag and dust phases by the salt melting process, as shown in Figure 2. The trend of the distribution ratio of the Co-60 was similar, regardless of the flux agent types. About 40 ~ 70% of the Co-60 was partitioned to the slag phase and only 5% of it was transferred to the dust phase. The removal ratio to the slag phase in this study is a little lower than that of the paper reported by Grabener et al. [2]. They reported that the Co-60 could easily be transferred to the slag with a decontamination factor of 25.

The Cs-137 was generally known that it had the low melting temperature and high vapor pressure. As shown in the Figure 3, the Cs-137 is mainly eliminated from the aluminum melt and transferred to the slag and dust phase up to 99%. The weight captured in the slag phase is respectively smaller than that of the Co-137.

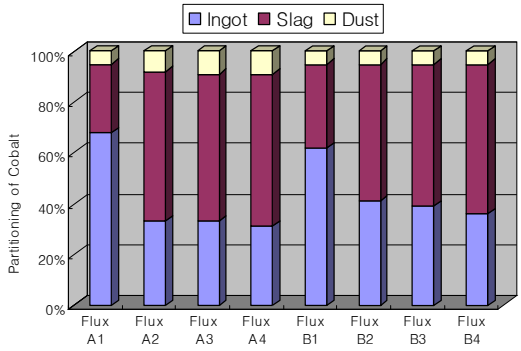

Figure 2. Distribution ratio of the cobalt in the ingot, the slag and dust phase (RI test).

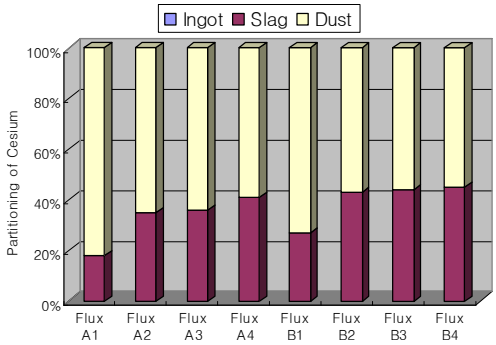

Figure 3. Distribution ratio of the cesium in the ingot, the slag and dust phase (RI test).

Table 2 shows the results of partitioning ratio for Co-60 and Cs-137 in the oxidation melting condition (air). The results of the partitioning for the each phase show the same trend with the results in the inert gas condition. Co-60 was transferred to the slag phase up to 70% and the Cs-137 was mostly partitioned to the slag and dust phases.

Table 2. Distribution ratio of the ingot, slag, and dust phase in the oxidation condition

Flux	Phase	Contamination [Bq/g]		Partitioning (%)	
		Co	Cs	Co	Cs
Flux A	Ingot	26	30	32	1
	Slag			62	57
	Dust			2	40
	Ingot	101	77	26	1
	Slag			70	57
	Dust			1	37
Flux B	Ingot	26	30	41	0
	Slag			55	32
	Dust			1	63
	Ingot	101	77	37	0
	Slag			59	33
	Dust			1	60

In the melting tests of the aluminum from TRIGA MARK Ⅲ research reactor, the decontamination factors of the aluminum wastes is given in Table 3. As shown in Table 3, we found that the Co-60 in the aluminum wastes is easily decontaminated.

Table 3. Decontamination factor (DF) for the aluminum melting from TRIGA MARK Ⅲ research reactor

Sample	Flux	Sample	Activity (melting)		DF
			Ingot	Slag	(Ingot)
		Co-60	Co-60	Co-60	Co-60
		[Bq/g]	[Bq/g]	[Bq/g]	
Al - Plate	Flux B	967.36	367.52	154.3	2.63
Al - Plate	Flux C	967.36	226.86	272.9	4.26
Al - Pipe	Flux A	190.61	48.13	3363.73	3.96
Al - Pipe	Flux B	85.96	17.8	1336.92	4.82
Al - Pipe	Flux D	110.17	26.13	1181.27	4.21

4. Conclusion

We found that the aluminum wastes generated from the decommissioning and decontamination process of the nuclear facilities were easily decontaminated by using the melting technology. The Co-60 was removed from the aluminum melt and transferred to the slag phase up to 75%, regardless of the aluminum specimen tests and the real aluminum wastes. The Cs-137 was mostly partitioned to the slag and dust phases.

REFERENCES

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