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Assessment of Distribution and Decontamination Factor during Melt Decontamination of Scrap Metal Contaminated with Natural Uranium

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1. Introduction

Metal waste generated from domestic nuclear operation for defense and commercial application has led to a growing stockpile of radioactively contaminated scrap metal, much of which is stainless steel [1-3]. A significant fraction of this material cannot be efficiently surface decontaminated. The burial of this material would be wasteful and expensive, since long term monitoring would be necessary in order to minimize environmental risk. Much of this waste consists of bulky equipments. In many case, this equipment contains valuable material that may be recycled. The piece of equipment considered frequently also has complex geometries, making extremely difficult, time-consuming and expensive to determine the exact location and level of radioactivity on the internal surfaces. After melting, however, the radioactivity may be precisely determined from samples of each ingot. Moreover, an ingot may be released for restricted or unrestricted reuse, or stored for decay to appropriated limits. Melting completely destroys components and, as a decontamination technique, is effective only for contaminants that are volatile or that concentrate in the slag rather than in the molten metal., the decontamination efficiency varies widely depending on the radioisotope present. The radionuclides remaining in the molten material are distributed homogeneously and effectively immobilized, thus reducing and this preserved valuable repository capacity..

This paper was to investigate a decontamination factor of melt decontamination process through a basic understanding of the major factors which govern the partitioning of natural uranium radionuclides between the metal, slag, and gas phases. Radionuclides which are captured by a slag phase may be stabilized within a leach resistant matrix.

2. Experiment

The lab-scale graphite arc melting furnace was used to verify the melting performance of contaminated metal with natural uranium on various operational conditions such as kinds of slag, weight of the added flux and concentration uranium. 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 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.

As shown in the Table 1, the scrap metal specimens were contaminated with the natural uranium together slag was added. The mixture was melted under an argon atmosphere for 5 minutes. After completing the scrap metal melting, the molten metal and slag was cooled and solidified in a copper mold. The ingot samples were taken as cylindrical shape. The slag was easily separated from the ingot. The ingot and slag samples were analyzed with ICP-AES (IRIS DUO, Thermo Elemental Co) for investigated to verify the decontamination characteristic of the ability to capture the uranium within the slag and ingot.

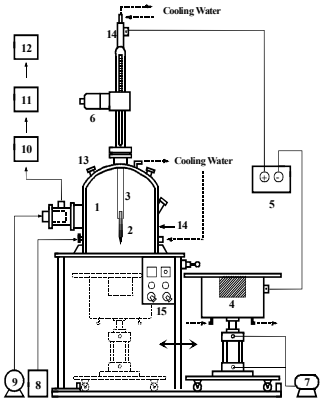

Figure 1. The schematic of the electric arc furnace.

Table 1. Composition and type of the slag.

Heat No.	Basicity index	Slag (wt%)	UO2 (ppm)	Composition (wt%)		
				SiO_2	CaO	Al_2O_3
1	0.52	10	500	50	30	20
2	0.82	10		40	40	20
3	1.28	10		30	50	20
4	1.49	10		30	54	16
5	2.32	10		10	60	30
6	3.14	10		15	70	15
7	1.49	5	500	30	54	16
8		7				
9		12				
10		15				
11	AB	10	500	**Al_2O_3**(14.5), **B_2O_3**(7.50), **CaO**(21.8), **Fe_2O_3**(0.2), **Li_2O**(0.5) **Na_2O**(0.5), **SiO_2**(55), **TiO_2** (0.5)		
12		10	1000			
13		10	2000			
14		10	4000			
15		10	8000			

3. Results

A total of 15 experiments were conducted with natural uranium (UO_2). According to the thermo-

dynamic calculation such as free energy calculation, uranium was completely removed from the ingot phase to slag phase under the equilibrium condition. However, the decontamination efficiency of the uranium in the practical melting system depend on the various experimental variable such as the slag type and composition, melting temperature and time, metal kind, and initial contaminant concentration

Figure 2 shows the distribution ratio of uranium in the slag. Most of the uranium was removed and transferred to the slag. Above 90% of the uranium was partitioned to the slag phase and not detected to the ingot. The natural uranium was transferred to the slag phase up to 97% about 1.5 of the basicity. The slag basicity seemed to have an influence on the melt decontamination mechanism of scrap metal. In experiment, the optimized distribution value of the uranium was achieved about 1.5 of the slag basicity.

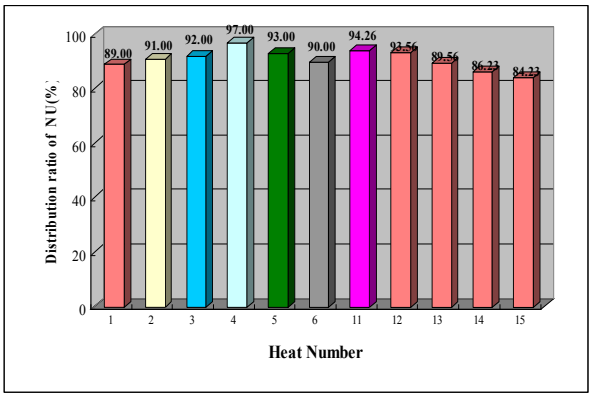

Figure 2. The distribution of uranium in the slag

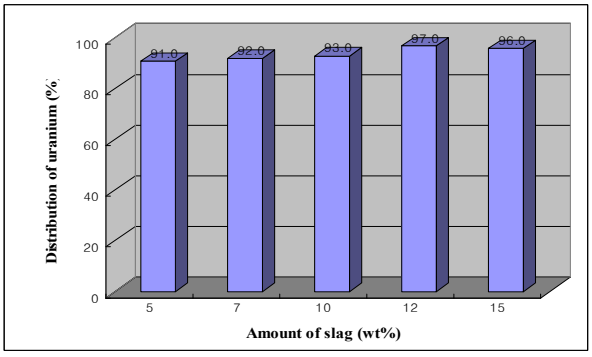

Figure 3. The distribution of uranium in the basicity index 1.49

Figure 3 shows the distribution ratio of uranium for added slag amount. The distribution of uranium was increased by increasing the amount of the slag. Because the capacity to capture uranium oxides with the slag phase with an increase of the slag obtaining potential oxidation.

Figure 4 shows the results of the decontamination factor for uranium in the ingot phase. The decontamination factor is defined as the concentration of initial UO_2 concentration divided by the concentration of UO_2 in the metal.

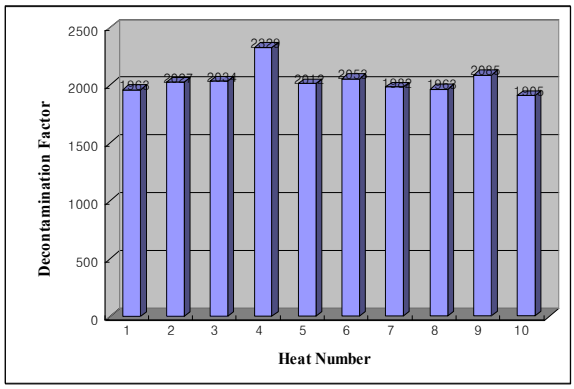

Figure 4. Decontamination factor of uranium (500ppm)

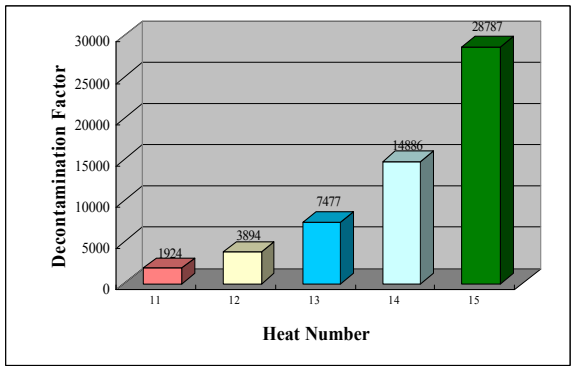

Figure 5. Relationship between decontamination factor and contaminated concentration

Figure 5 shows the results of the relationship between DF and contaminated concentration. Graphs of the UO_2 concentration in the metal versus the initial UO_2 concentration at each test are linear, indication that thermodynamic equilibrium was achieved. A decontamination factor of more than about 2000 for the uranium from the ingot could be achieved due to their transportation from the ingot to the slag.

4. Conclusion

We found that the scrap metal wastes contaminated with uranium oxide (UO_2) were easily decontaminated by using a melting technology. The uranium oxide was removed from the metal and transferred to the slag phase by up to 97%. The optimum value of the slag basicity for the decontamination in the melting of steel wastes was about 1.5.

REFERENCES

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