VOLUME REDUCTION OF CONTAMINATED METAL WASTE

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INTRODUCTION

The methodologies and philosophies of disposal of low-level radioactive and transuranium-contaminated wastes have received much attention over the past few years. The desire to minimize shallow land burial and extend the useful life of existing burial space has prompted increased efforts for volume reduction. For radioactively contaminated waste metals, the primary volume reduction method practiced thus far has been rather careful packing to optimize the density of contaminated metals requiring retrievable storage. Two approaches are presently being investigated to minimize the volume of metal scrap through melting. One approach is the simple volume reduction achieved by transforming the metal to its most dense form by melting. The other approach involves removing the metal from the waste stream entirely by the ability to remove contaminants from the metal by melting and the ability to verify the radioactive nuclide content of the resulting ingots. Much of the metal waste is "suspect waste" simply because it has been exposed to radioactive materials and cannot be certified as uncontaminated because of complexity, cracks, crevices, etc. The uniformity of ingots after melting may allow the metal to be certified as uncontaminated.

Previous investigators have shown that uranium can be effectively removed from many metals by melting under an oxidizing slag.[1] More recently, plutonium and americium have also been shown to concentrate in the slag for several metals.[2] In previous work[3] we proposed a conceptual treatment plan illustrated

[a] Work supported by the U.S. Department of Energy under contract 7405-eng-26 with Oak Ridge National Laboratory. Rockwell International, Rocky Flats Plant, is Lead Contractor for the National Transuranium-Waste Program.

in Fig. 1 and consisting of (1) sorting the metal scrap into alloy types insofar as possible, (2) size reduction of the scrap to fit in the melting equipment, (3) further alloy segregation by sequentially raising the temperature of mixed scrap lots and allowing the low-melting alloys to "drip-melt" out, (4) induction melting of the high-melting alloys, and (5) casting all alloy types into easily handled and packaged ingot shapes. It is advantageous to remove the low-melting metals before induction melting for several reasons. The low-melting alloys cause fuming during induction melting, deteriorate the lining of the induction melter, and lower the value of the ferrous scrap for potential reuse. The drip-melting tends to decontaminate the metals as the

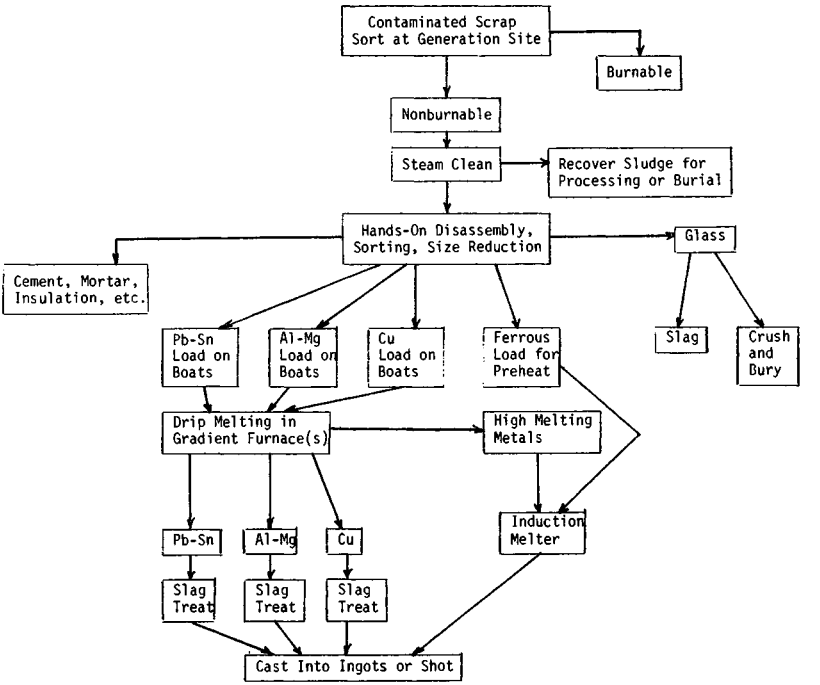

Fig. 1. Flow Chart of Conceptual Plan for Handling Contaminated Metal Waste

surface contaminants stay in the dross resulting from surface oxides. Aluminum scrap is decontaminated to some extent by drip-melting whereas it is not decontaminated by melting under slag.

This paper presents the results of two different types of experiments. We made laboratory melts of various metals to compare the observed partitioning of uranium to the slag with that calculated from thermodynamic considerations. The partition ratio is defined as the amount of uranium in the slag divided by the amount in the metal. We also conducted an engineering-scale demonstration in which a typical batch of metal scrap was contaminated with UO_2 and processed through the proposed handling plan including mechanical size reduction, drip melting, and induction melting.

LABORATORY-SCALE MELTING

Laboratory-scale experiments were run in two different ways: (1) metals were melted in contact with uranium metal chips and UO_2 powder and then remelted under a slag to attempt to remove the uranium, and (2) metals were melted under a slag containing 0.3 wt % U and the transfer of uranium to the metal was measured. The first method presented difficulties in getting the uranium in solution in many of the metals. It also revealed a characteristic that will have to be guarded against in a production facility in that solidifying metal can entrain and mechanically trap the uranium oxide and give inhomogeneous ingots with areas high in uranium. More reproducible results were obtained in the second method, where uranium was added to the slag and the transfer of uranium to the metal melt was measured. Some typical results are given in Table I. Although the experimental values for the partition ratio tend to agree in order of sequence with the calculated values, the experimental values are different by many orders of magnitude from the calculated values. The reasons for the gross discrepancies are most likely those listed in the reference,[3] that is, assumptional errors in making the calculations (specifically assuming ideal solution and Henry's Law constants of unity). These results show that the calculated partition ratios can be used only as a guide experimentally determining whether the contaminant will partition to the slag. It should also be pointed out that when the uranium is prealloyed with aluminum, partition ratios of only 2 to 3 are observed instead of 190 as in the table.

Table I. Results of Equilibrating Several Metals with Slag Containing 0.3 wt % U

Metal	Equilibration Temperature (°C)	Uranium Concentration In Metal (ppm)	Partition Ratio	
			Experimental	Calculated[a]
Sn	550	2.5	1.2×10^3	10^{42}
Pb	550	<2	$>1.5 \times 10^3$	10^{56}
Zn	550	<2	$>1.5 \times 10^3$	10^{29}
Al	700	16	1.9×10^2	10^{-3}
Cu	1100	5	6×10^2	10^{24}
Fe	1600	<2	$>1.5 \times 10^3$	10^{11}
Ni	1600	4	7.5×10^2	10^{14}

[a]From reference 3.

We conducted experiments on the laboratory scale to test drip melting as a technique for decontamination as well as for separation of the low-melting alloys from the higher melting ones. The simple technique used is illustrated in Fig. 2. A

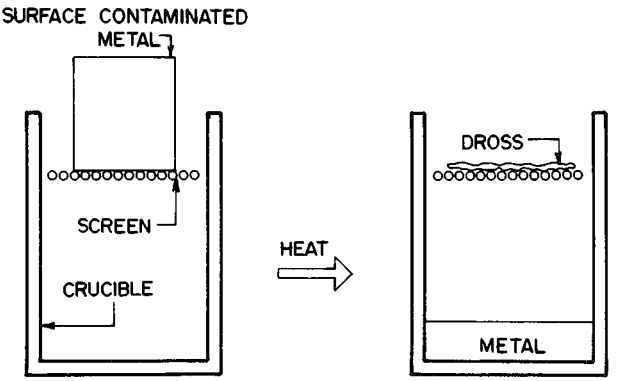

Fig. 2. Schematic of Drip-Melting Equipment

surface-contaminated piece of metal is placed on a screen in a crucible and then heated to above its melting point. The contamination tends to remain on the screen with the oxide dross. The results of experiments with several metals are in Table II. This method is fairly successful in removing surface contamination from aluminum.

Table II. Results of Drip-Melting Several Surface-Contaminated Metals

Metal	Uranium Concentration, ppm	
	In Metal	In Dross
Aluminum	15.8	2100
Pb-Sn Solder	1.6	955
Copper	1.4	3400

ENGINEERING-SCALE DEMONSTRATION

A load of 218 kg of mixed metal scrap from a metal scrap bin shown in Fig. 3 was processed through the proposed scrap metal handling process (Fig. 1) as an engineering-scale demonstration. Figure 4 shows the scrap after it was mechanically cut into pieces that would fit into our 0.13-m-diam by 0.15-m long melting container. At this point the scrap occupied a volume of 0.395 m^3 as opposed to 1.60 m^3 before size reduction — a 4:1 volume reduction. The scrap was easily separated by appearance into 15.2 kg copper, 10.2 kg stainless steel 88.5 kg aluminum, 65.4 kg steel, and 39.9 kg of mixed metals containing mostly copper wire with insulation and galvanized steel. These metals were contaminated by painting with a UO_2-alcohol slurry and melted separately under slag or drip-melted for the aluminum (except for the mixed metals, which could not be melted for lack of an adequate fume handling system — an equivalent volume of steel was substituted for this). The total ingot volume after melting was 0.0494 m^3 with about 0.003 m^3 of slag. This volume represents a further volume reduction during melting of 7.5:1 giving a total volume reduction of 30:1. Figure 5 shows typical ingots.

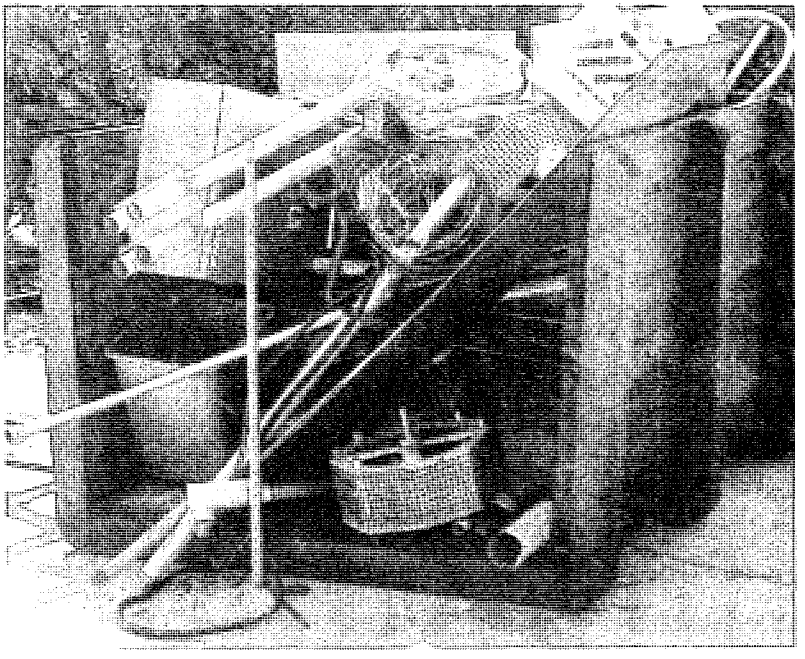

Fig. 3. Scrap Processed for Engineering-Scale Demonstration — Volume 1.60 m^3

Analysis for uranium by fast-neutron activation of the metals and slags shows that the decontamination was very successful. The uranium content of the steel ingots ranged from 0.09 to 4.2 ppm with an average of 1.55 ppm. The uranium content of the slags ranged from 1040 to 2220 ppm with an average of 1450 ppm (partition ratio of 940). The uranium content of the stainless steel ranged from 0.06 to 0.13 ppm with 1500 ppm in the slag (partition ratio of 15,000). The copper ingots contained 0.07 ppm U and the slag 1250 ppm (partition ratio of 18,000). The aluminum ingots resulting from the drip melting of the surface-contaminated aluminum scrap contained 4 ppm U while the dross contained 25 to 75 ppm.

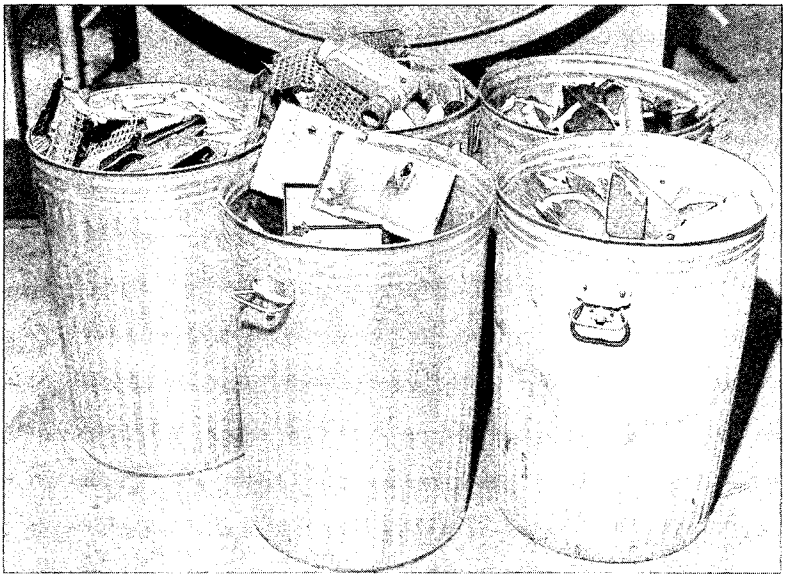

Fig. 4. Scrap for Fig. 3 After Mechanical Size Reduction — 4:1 Volume Reduction

DISCUSSION OF RESULTS

It is obvious that volume reduction will be achieved by melting metal scrap into ingots of a shape and size desirable for the end disposition of the metal. The amount of volume reduction achievable will vary greatly depending on the original configuration of the scrap. Another advantage accrues by melting, which, when combined with the decontamination achieved, may be more important than the volume reduction. This advantage is the ability to accurately verify the radioactive nuclide content of the metal ingots through a combined effort of quality control to assure that the ingots are homogeneous along with inspection of all ingots by passive gamma signature analysis.

Once the nuclide content has been verified, the disposition of the metal depends on the cleanliness achieved and the institutional constraints. If currently proposed regulations are

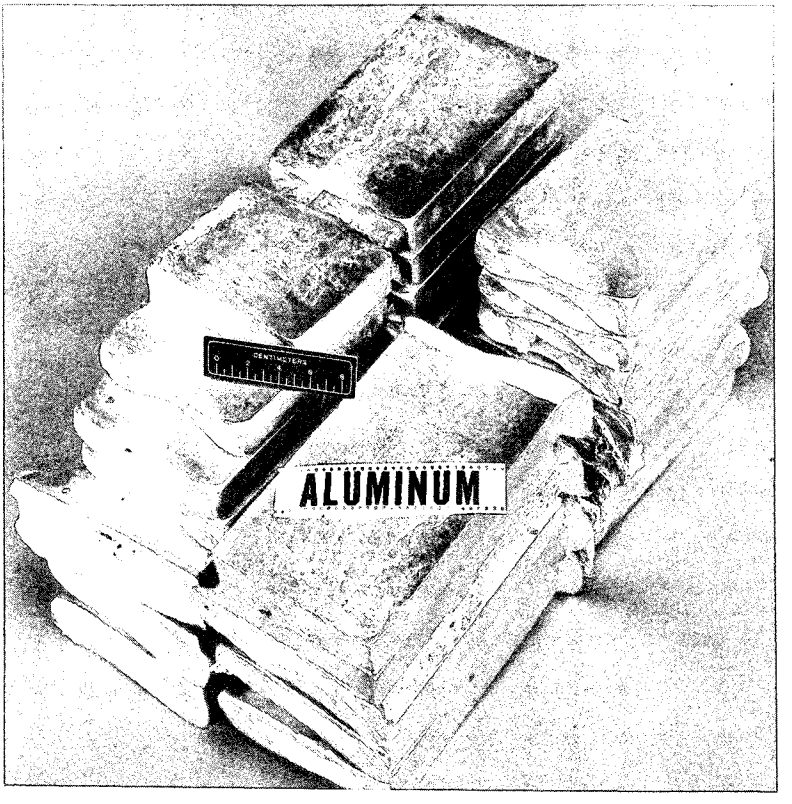

Fig. 5. Typical Ingots Resulting from the Scrap in Fig. 3 — 30:1 Total Volume Reduction

approved, much of the metal may be sold as clean scrap metal. If not, the metal may be treated as industrial waste and shallow-land buried rather than placed in more complex and expensive waste burial or placed in retrievable storage as transuranium waste.

REFERENCES

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3. G. L. Copeland, R. L. Heestand, and R. S. Mateer, *Volume Reduction of Low-Level Contaminated Metal Waste by Melting — Selection of Method and Conceptual Plan,* ORNL/TM-6388 (June 1978).