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## **Evaluation of Density Separation and Other Treatment Methods for Plastic Media Blasting (PMB) Waste**

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**MANAGED BY  
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Chemical Technology Division

EVALUATION OF DENSITY SEPARATION AND OTHER TREATMENT METHODS  
FOR PLASTIC MEDIA BLASTING (PMB) WASTE

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## ABSTRACT

*The United States Air Force has developed plastic media blasting (PMB) to replace solvent paint stripping of its aircraft. This paint blasting operation generates a waste stream of mainly pulverized plastic, but the stream also contains enough paint pigments to make the PMB waste RCRA hazardous. A Phase I study identified density separation as the preferred treatment alternative to land disposal of the entire PMB waste stream in a hazardous landfill. This study found density separation to be a less attractive alternative to self-encapsulation, solidification/stabilization (S/S), and low-temperature ashing. Self-encapsulation resulted in a volume decrease but only moderate improvement in Toxicity Characteristic Leaching Procedure (TCLP) performance. Solidification/Stabilization (S/S) into cementitious waste forms resulted in excellent TCLP performances, but volume increases. Low-temperature ashing resulted in dramatic volume decreases, but off-gas control is required to contain all the RCRA metals. The resulting ash must be stabilized (e.g., S/S) to meet TCLP limits.*

## 1. INTRODUCTION

The United States Air Force (USAF) developed plastic media blasting (PMB) to strip paint from its aircraft to protect both its aircraft and the environment. Normal blasting (e.g., using sand) would damage the softer metal of the aircraft and was precluded. Thus, paint stripping had been done using solvents, resulting in the release of solvent vapors to the atmosphere and the generation of an organic liquid hazardous waste (the solvent), which also contained hazardous metals from the paint pigments. The USAF developed PMB using five different plastic media: four thermoset polymers for Types I-IV media and one thermoplastic polymer for Type V medium. Plastic media blasting waste from Types II and V were studied in this work. Development of the PMB eliminated the air emissions of the solvents and the organic liquid waste stream, an improvement for both environmental risk and personnel safety. Despite this improvement, one of the contaminants still remained—the paint.

As the PMB technique was developed, it became necessary to screen the plastic particles before recycling in order to remove sand and grit particles that were damaging to the aircraft. The material that passes through the screen constituted the PMB waste stream and consisted of pulverized plastic dust and pulverized paint, as well as a small amount of sand and grit. The pulverized paint made this PMB waste stream characteristically hazardous by the EP-Toxicity test, meaning it had to be disposed of as a RCRA waste. The bulk of this waste stream was the innocuous pulverized plastic, and the USAF initiated a program to study ways of treating the waste to make it non-hazardous or to remove the paint from the plastic, thereby reducing the size of the hazardous waste stream. The first phase, Phase I, of this study screened several treatment

alternatives, issued a report on the results (ref. 1), and proposed density separation as the alternative most likely to succeed.<sup>1</sup> For Phase II, Oak Ridge National Laboratory (ORNL) was to scale up the density separation treatment identified in Phase I and conduct an engineering-scale demonstration of density separation at an air force base (AFB). The density separation tests conducted in Phase I gave contradictory results, and the only successful test was done using carbon tetrachloride, a hazardous organic chemical. For this reason, more bench-scale development of density separation was required, and this report gives the results of this bench-scale development.

At the beginning of this development effort, it was decided that the use of organic liquids should be avoided because the only organic liquids with the necessary density were halogenated, which were hazardous wastes, listed wastes, or ozone attackers (sometimes all three). Instead, efforts were concentrated on developing density separation using aqueous solutions. Considering the limited success with all the options during Phase I, including density separation, three other options were investigated during this bench-scale effort: (1) encapsulation of the PMB waste in the thermoplastic medium (Type V), (2) stabilization/solidification (S/S) of the PMB waste, and (3) low-temperature ashing with S/S of the ash. Regulatory rules limited the availability of PMB waste samples through much of this bench-scale project. For this reason, most of the early development work was conducted using gram quantities, subjective observation, qualitative analysis, and semi-quantitative analysis. Toward the end of the project, enough sample was finally attained to allow quantitative evaluation of the development efforts. As will be seen, these quantitative results demonstrated that the density separation that had been developed was only removing a fraction of the paint and the aqueous solution was extracting chromium (not unexpectedly, because the aqueous solubility of chromates was recognized as a potential problem from the beginning).

During the course of this project, the third-third of the land ban restrictions was promulgated and the Toxicity Characteristic Leaching Procedure (TCLP) was formally published and replaced the EP-Toxicity test. These two actions changed the objectives of the USAF. Rather than seeking to minimize the size of a waste stream that fails the EP-Toxicity, the USAF must now find a treatment that passes the TCLP test before they can land dispose of any PMB waste as an industrial waste.

## 2. BACKGROUND

The literature search revealed some references to the development of PMB and its associated equipment, but only two references concerned disposal of the PMB waste.<sup>1,2</sup> The first reference was to the Phase I part of this program. The second was work done at Argonne National Laboratory for the U.S. Navy on incineration of the PMB waste. In this prior work, PMB waste was incinerated between 690°C and 815°C in an excess of air, and the ash was found to be concentrated in metals. Two ashes were also leached in the TCLP. The extract concentrations for an ash generated at 750°C were below the TCLP limits, while the cadmium extract concentration of an ash generated at 766°C exceeded the TCLP limit.

The following five plastic media were listed in the Military Specification document:<sup>3</sup>

Type I	Polyester	(thermoset)
Type II	Urea formaldehyde	(thermoset)
Type III	Melamine formaldehyde	(thermoset)
Type IV	Phenol formaldehyde	(thermoset)
Type V	Acrylic	(thermoplastic)

According to Hill AFB and McClelland AFB, only Type II and V were being used, and Type II use was in decline. McClelland AFB also supplied typical results for Type V waste in two California leaching tests: the Soluble Threshold Limit Concentration (STLC) and Total Threshold Limit Concentration (TTLC) (results given in the Appendix).

### 3. EXPERIMENTAL

#### 3.1 TREATMENTS

##### 3.1.1 Density Separation

Density separation was tested by centrifuging and gravity settling. Samples were centrifuged on an IEC Centra-8 laboratory centrifuge at 1000 rpm for time periods ranging from 10 min to 1 h (usually 15 min). The PMB waste quantity that could be centrifuged was limited to a few grams. Gravity settling was typically done in beakers, preceded by mixing and assisted by vibration or recirculating through a pump. The screening studies were limited (by sample availability) to batches of 1–20 g in 250-mL or 500-mL beakers. The large batches were 200–1000 g in 4-L beakers. The time allowed for settling varied from several hours (usually overnight) to several days. The photograph in Fig. 1 illustrates the appearance and relative amounts of the dry product after a large batch density separation.

##### 3.1.2 Plastic Encapsulation

The Type V waste is essentially polymethylmethacrylate (PMMA) powder, a thermoplastic that can be softened and molded, unlike Type II (a thermoset). This plastic dust was molded into plastic pellets using a Simplimet II phenolic press. The temperature control was adjusted from about 150°C (for phenolic resin) to about 170°C (for softening PMMA). After reaching temperature, the 1 1/4-in.-diam. die of the phenolic press was filled with about 20 g of the waste dust. The powder was preheated for 10 min, a mechanical pressure of 7000 lb<sub>f</sub> (5700 psi) was applied, the sample was held at about 170°C under pressure for about 20 min, and the sample was allowed to cool under pressure for about 20 min. (Note that the pressure applied was mechanical and the die was not airtight; that is, the air in the powder void volume could escape as the powder was compressed into a pellet. As this air escapes, the mechanical pressure decreases and must be adjusted to maintain the target pressure. Also, the Type V waste loses about 1 wt % of mass upon heating at 110°C, ostensibly methylmethacrylate (MMA) monomer and sorbed water. Preheating the powder helps prevent trapping such emissions in the softened, compressed pellet.) This procedure yielded plastic pellets of PMMA about 3.15 cm in diameter by 1.89 cm high (1.25-in. diam x 0.75 in.). These pellets encapsulated the paint, and the Type II waste if present, in the

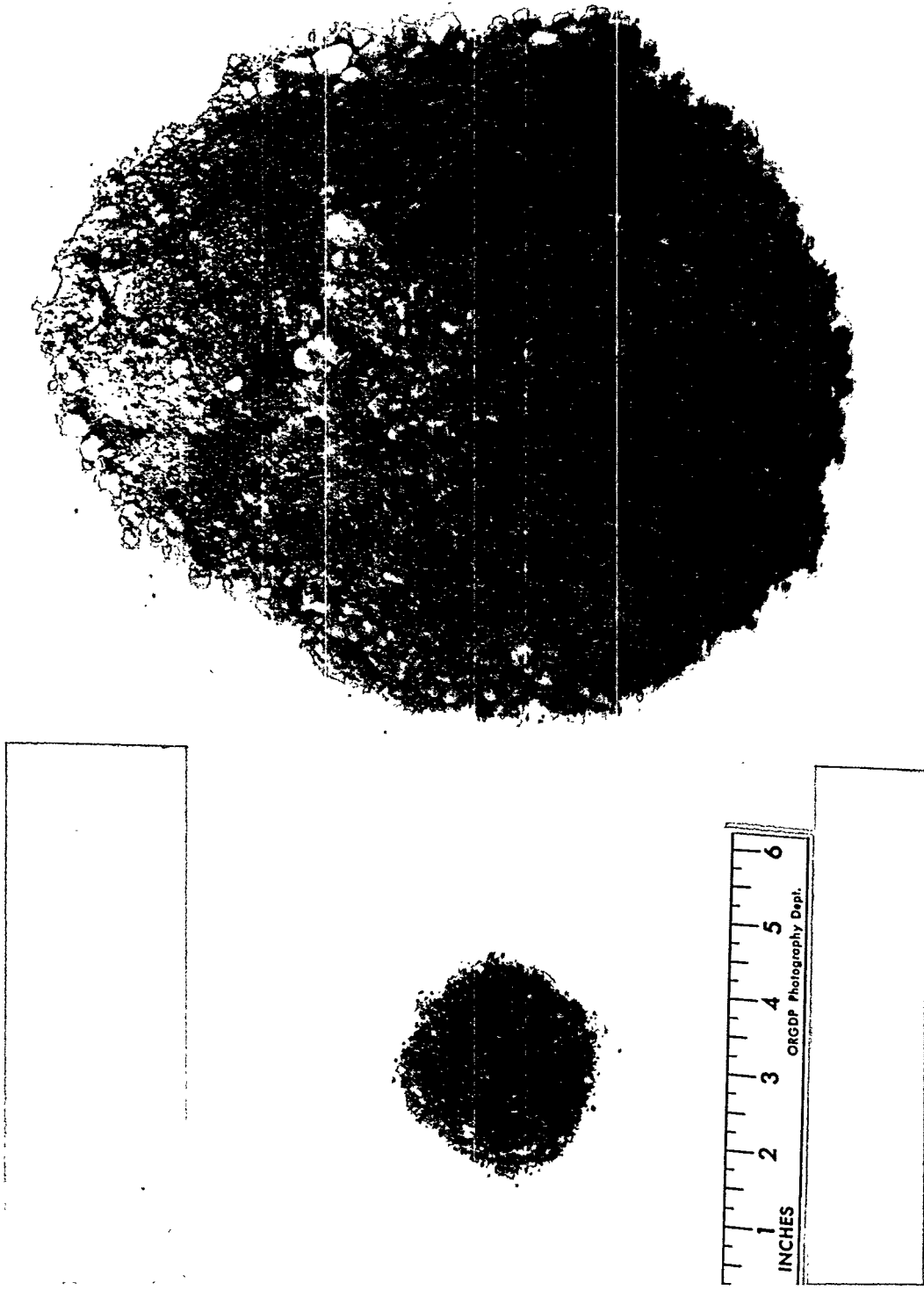


Fig. 1. Photograph of a large batch of dry Type V waste after density separation using a  $K_2CO_3$  solution [heavy fraction (left), light fraction (right)].

Type V waste. (This was the final procedure after some trial-and-error development.) The photograph in Fig. 2 illustrates the appearance of the Type V waste pellet.

### 3.1.3 Cementitious Fixation

The PMB waste was essentially a dry powder and was blended for 1 h on a V-blender with a ground blast furnace slag (GBFS) from the Standard Slag Company (Youngstown, Ohio) and Type I Portland cement from the Dixie Cement Company (Knoxville, Tennessee). This dry blend was composed of 50 wt % PMB waste, 45 wt % GBFS, and 5 wt % cement. (The main binding agent was GBFS, but GBFS requires a caustic activator such as cement.) This dry blend was mixed (using a Hobart mixer with a flat open-structured blade) with the minimum amount of water to achieve a moist, workable paste. The resulting mix ratio was 2 kg dry blend/L water (16.7 lb/gal), (water/cement ratio of 10, water/GBFS ratio of 1.11, water/binder ratio of 1.0, water/solids ratio of 0.5). The grout composition was 33.3 wt % water, 33.3 wt % PMB waste, 30.0 wt % GBFS, and 3.3 wt % cement. This grout was packed as 2-in. cubes in a stainless steel (SS) mold sprayed with silicone (to act as a mold release agent) and stored (uncovered) in a humidity cabinet at room temperature for curing. The hardened cubes were removed from the molds after curing 17 d and were submitted for TCLP testing.

### 3.1.4 Low-Temperature Ashing

Low-temperature ashing was used to prepare the small samples from the density separation screening tests for energy dispersive X-ray (EDX) analysis and was also suggested as a treatment alternative for the PMB waste to reduce the waste volume and concentrate the metals in an ash. The ashing was done using open ceramic crucibles in a Thermolyne Type 1400 laboratory furnace in room air. The objective was to drive off all the organic compounds (including the PMB plastic) as combustion gases and vapors while retaining the pigment compounds. To minimize vaporization of the metallic species, low ashing temperatures (400–600°C) were desired. Some subjective testing indicated that satisfactory ashing was achieved at 500–600°C. A temperature of about 600°C was used to prepare the ash samples for both EDX analysis and for total metals analysis. In addition, the mass losses (during ashing) were measured at a couple of lower temperatures.

## 3.2 ANALYTICAL METHODS

### 3.2.1 Scanning Electron Microscope

The scanning electron microscope (SEM) was used in the following three ways during this project to help characterize the PMB waste: (1) SEM imaging, (2) backscatter imaging, and (3) EDX analysis. Regular SEM photomicrographs of the Type V waste were generated at different levels of magnification to help illustrate the size range of the waste, the morphology of the waste, and the relative degree of attachment of particles to each other (e.g., whether the particles appear as a loose jumble or whether they appear embedded in one another). Backscatter refers to the electrons (from the electron beam) that undergo elastic scattering inside the sample and are re-emitted from the sample. The proportion of the electrons that are backscattered is known to increase as the mean atomic number of the material increases, allowing contrasting (in the black and white imaging of SEM) between materials of different mean atomic number. In other words, backscatter imaging highlights the presence of the metals or metallic compounds of the paint

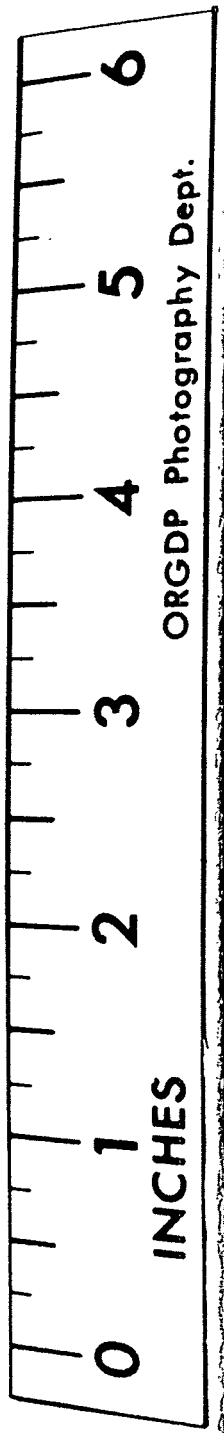
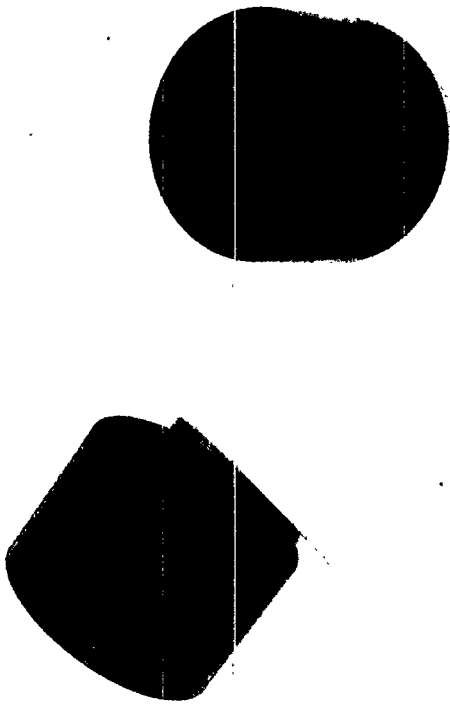


Fig. 2. Photograph of self-encapsulated Type V waste pellets.

pigments in the plastic dust of the PMB waste. The EDX analysis was used as a semiquantitative tool to test the degree of separation achieved during the density separation screening tests.

In the screening tests, density separation was attempted on small samples, the light and heavy fractions were ashed at low temperature (600–620°C), and an EDX scan (covering about 3 cm<sup>2</sup>, or about 0.5 in<sup>2</sup>) of the ash was made. Elements were qualitatively identified from the peaks on the resulting spectrograph, and the peak heights served as a quantitative estimate relative to each other. Cobalt was used as a tracer and served to translate the peak heights into the estimated mass in the ash (and PMB waste). The PMB waste did not contain measurable amounts of cobalt, so a known mass of cobalt was dispersed in the sample. The peak height for cobalt was related to this mass; hence, the other peak heights relative to cobalt could be translated into masses for those elements. It was recognized that this did not give an accurate bulk composition for these samples (an estimate within 20% of the true value at best), but it provided a quick feedback for the effectiveness of the density separation screening tests along with inspection of the product under an optical microscope.

### 3.2.2 Optical Microscope

An optical microscope was used, typically at 50× or 100×, to subjectively judge the effectiveness of a density separation screening test. The product was viewed using reflected light. Polaroid photographs were taken of some of these products on another optical microscope and photographs made of these polaroid positives.

### 3.2.3 Total Metals Analysis

Samples were submitted to K-25 Analytical Chemistry (an EPA-approved laboratory) for total metals analysis. The plastic dust samples were analyzed by two techniques: (1) extraction (EPA Method 3050) followed by analysis of the extract (EPA Method 6010, inductively coupled plasma spectrophotometry, or ICP) and (2) ashing in Paar bombs using an oxygen atmosphere at 1000°C, or higher (ASTM-D3761), followed by extraction of the ash with HNO<sub>3</sub>, and analysis of the extract (EPA Method 6010). Finally, the concentrated K<sub>2</sub>CO<sub>3</sub> solution was analyzed by ICP for the four metals of most interest: barium, cadmium, chromium, and lead. (Note that neither EPA Method 3050 nor HNO<sub>3</sub> always dissolves 100% of a solid sample. In other words, the total analysis reported for the solid samples represents what was extracted using this method but may not be 100% of a given metal that was actually present in the sample.)

### 3.2.4 Toxicity Characteristic Leaching Procedure

Samples were submitted to K-25 Analytical Chemistry (an EPA-approved laboratory) for Toxicity Characteristic Leaching Procedure (TCLP) testing. Since the PMB wastes did not contain the characteristically hazardous organics and total metals analysis indicated that only barium, cadmium, chromium, and lead were of concern, the TCLP extracts were only analyzed for barium, cadmium, chromium, and lead. The TCLP test extracts a bed of particles (<9.5 mm). The plastic dust was extracted directly, without size reduction, but the solidified waste forms (plastic pellets and cementitious cubes) required size reduction. The cementitious cubes were brittle and were easily smashed or crushed, but the plastic pellets were tough and were reduced in size by first freezing in liquid nitrogen and then smashing.

#### 4. SALT SELECTION FOR DENSITY SEPARATION

The density of the plastic media was about 1.2 kg/L for Type V and about 1.5 kg/L for Type II. Quite concentrated salt solutions were required to float these plastics. Table 1 lists some candidate salts along with the density and viscosity ranges at normal temperatures for their aqueous solutions, as reported in standard handbooks. Table 2 lists the theoretical paint film densities calculated by the suppliers for a partial list (obtained from McClelland AFB) of the paints used on A-10 and A-7 aircraft. If the paint densities listed in Table 2 were representative of the paints in the PMB waste containing hazardous metals, then density separation from Type V plastic seems feasible, but density separation from Type II plastic does not appear attractive. Although McClelland AFB indicated this list of paints was representative for their aircraft, the Deft Company contact indicated that these paints did not contain lead or cadmium pigments and only contained trace amounts of heavy metals; that is, he considered these paints to be non-hazardous. Since it is possible that this partial list does not include the paints with hazardous metals, a density range for paints containing lead, chromium, and cadmium pigments was estimated from the theoretical dry film density of polyurethane (1.17 kg/L) and epoxy primer (1.13 kg/L), the range of pigment contents reported by Tappscott et al.<sup>1</sup> (5-15 wt %), and the densities of the pigment compounds. This calculation gave a possible density range for dry paint of 1.2-2.5 kg/L. The Type V plastic density was at the very low end of this range, still making it look feasible, but the Type II density lay well within this range, meaning there may be little or no density difference between the paint and Type II plastic. Most of the salts listed in Table 1 are halide salts, which can cause corrosion problems and require corrosion-resistant materials. Two nonhalide candidates were tested: (1) a low-viscosity salt,  $K_2CO_3$ , and (2) a high-viscosity soluble organic, sucrose. The salt with the maximum density range,  $CaBr_2$ , was also tested. Thus, screening tests were done using aqueous solutions of  $K_2CO_3$ ,  $CaBr_2$ , and sucrose, and large batch density separations were attempted with  $K_2CO_3$  solutions.

#### 5. RESULTS

##### 5.1 CHARACTERIZATION OF THE PMB MEDIA AND WASTE

###### 5.1.1 Scanning Electron Microscope

Scanning Electron Microscope photomicrographs illustrated the size range and morphology of the Type V waste over a magnification range from 289 $\times$  to 3950 $\times$ . Subjectively by eye, this waste is a light gray dust. Large flakes of paint can be found if one looks for them, but they are not readily apparent. For this reason, it was suspected that the bulk of the paint was not present as these large flakes, although the mass in such large particles might be significant. In addition, the Type V waste has a noticeable odor. Since the virgin material also has this odor, although fainter, it was suspected to be MMA monomer. Drying at 110°C removed the odor and was believed to vaporize the monomer and sorbed water. The photomicrographs made it evident that the bulk of the plastic dust was around 100 to 200  $\mu m$  but that smaller particles were present, extending into the submicron regime. The sample was on a tungsten support, readily visible in the backscatter image. The brighter specks scattered throughout the backscatter image were believed to be paint, with one paint chunk of 6-7  $\mu m$ . The plastic appeared as dark chunks in the backscatter images.

Table 1. Candidate aqueous solutions for density separation of PMB waste

Component	Density range (kg/L)	Viscosity range (mPa·s)
LiBr	1.0-1.8	
NaCl	1.0-1.2	1.0-2.0
NaBr	1.0-1.4	1.0-1.9
NaI	1.0-1.8	1.0-2.0
KBr	1.0-1.4	1.0-1.1
KI	1.0-1.6	0.9-1.2
K <sub>2</sub> CO <sub>3</sub>	1.0-1.5	1.0-9.4
RbCl	1.0-1.5	~1.0
RbBr	1.0-1.7	~1.0
RbI	1.0-1.9	~0.9
CsCl	1.0-1.9	1.0-1.2
CaCl <sub>2</sub>	1.0-1.4	1.0-8.8
CaBr <sub>2</sub>	1.0-2.4	
CaI <sub>2</sub>	1.0-3.1	
SrCl <sub>2</sub>	1.0-1.4	1.0-2.6
FeCl <sub>3</sub>	1.0-1.4	1.0-11
Glycerol	1.0-1.3	1.0-1500
Sucrose	1.0-1.4	1.0-1600

Table 2. Theoretical paint film densities

National stock no. (NSN) 8010-	Mil. spec. no.	Color code	Dry film density (kg/L)	Supplier
001818255	83286 <sup>a</sup>	16473	1.47	Deft Co.
001818282	83286	17875	1.52	Deft Co.
001818285	83286	37875	1.53	Deft Co.
004825653	83286	31136	1.39	Deft Co.
011046530	83286	37038	1.31	Deft Co.
P03GN182	83286	34102	1.48	Deft Co.
P03GN183	83286	34092	1.48	Deft Co.
P03GY245	83286	34092	1.48	Deft Co.
P03GY362	83286	26118	1.53	Deft Co.
012928894	85582	Green Primer	1.74	Deft Co.
004591756	83231 <sup>b</sup>	17038	1.10	Caap Co.

<sup>a</sup>Polyurethane top coat.

<sup>b</sup>Carbon black encapsulated in polyurethane resin; no hazardous metal pigments.

### 5.1.2 Energy Dispersive X Ray

The effectiveness of separation by centrifuge, or gravity, was mainly judged by inspection of the product under an optical microscope because the EDX analysis was too insensitive for true quantitative analysis and too inconsistent to trust. The EDX analysis did demonstrate that the Type II virgin plastic contained significant amounts of barium, one of the metals of concern in the waste stream. This virgin plastic left a residue of 2-3 wt % upon ashing, and the majority of this ash was barium according to EDX analysis. The Type II waste leaves 4-6 wt % ash consisting of more than 70 wt % barium by EDX. During the early screening tests, the Type V waste left 1-3 wt % ash containing about 20 wt % barium, and the virgin material left <1 wt % ash containing about 15 wt % barium. The bulk (40-50 wt %) of the Type V ash was silicon for both the virgin plastic and the waste. These results were obtained whether ashing in a ceramic boat or on nickel foil, so the silicon was not being scraped from the ceramic. Because ashing was so much more complete for the virgin plastic, some incombustible material, including silicon, was added during blasting. This was not inconsistent with the blasting operation since the plastic media was collected on the floor and recycled during blasting, allowing sand and grit to be swept up in the recycled material. The presence of sand and grit in the recycle has been known, and size classification was added to the recycle operation as a means of removing this sand and grit as well as the pulverized paint and plastic. One other observation made while ashing these samples for EDX analysis was that the volume of the Type V appears to become negligible after ashing, but the volume of the Type II appears not to change significantly during ashing. Apparently, some filler, probably a barium compound, maintained the original shape of the Type II plastic, even though the plastic had been decomposed.

### 5.2 SCREENING TEST RESULTS FOR DENSITY SEPARATION

The screening tests were encouraging and indicated that density separation of both Type II and Type V wastes was possible, based on the subjective, qualitative evaluation used. Little or no quantitative data were generated from the screening tests. The material that fell to the bottom during the later tests was almost completely large paint flakes (hundreds of microns in the large dimension, but only a small fraction of that in thickness). The large batch contained more plastic in the "dirty" fraction. The "clean" fraction was never completely freed of dark specks (taken to be paint), but heroic efforts could make it appear almost clean.

The specks visible under the microscopes (optical and SEM) were on the order of microns; that is, they were comparable to the large chunk observed highlighted in the backscatter SEM. No large flakes were highlighted in the sample, implying no large paint flakes were present. The odds may be against a large flake being included in a representative small subsample used in the SEM, unless the sample is biased and a large flake is purposely sought out and included.

Tests with sucrose solutions in the density range of 1.2-1.3 kg/L did not appear to give good separations for the Type V waste, even using the centrifuge. Use of a wetting agent (Turgitol NP-10) had no apparent beneficial effect. (In fact, neither water nor any of the solutions tested appeared to have any trouble wetting the plastic waste, with or without the wetting agent.) Potassium carbonate solutions with densities <1.25 kg/L appeared to fare no better, but those with densities of 1.28-1.33 kg/L were immediately successful, whether using the centrifuge or gravity settling. The high pH (12) of these solutions was suspected of playing an important role in deagglomeration of the paint from the plastic, since sucrose solutions of similar densities were

not nearly as successful. Gravity separation appeared to work for both Type V waste and Type II waste using a  $\text{CaBr}_2$  solution at a density of 1.28 kg/L (pH of 9) for Type V and 1.60 kg/L for Type II. Upon inspection of the products under the optical microscope, the separations did not appear as clean as had been achieved using  $\text{K}_2\text{CO}_3$  on Type V waste, but further development might improve the performance. Both the  $\text{K}_2\text{CO}_3$  solution and  $\text{CaBr}_2$  solution changed from colorless to light yellow during the density separation of the Type V waste, an indication that the chromate pigment was extracting into the solution (later verified for the  $\text{K}_2\text{CO}_3$  solution). However, the  $\text{CaBr}_2$  solution remained colorless during the density separation of the Type II waste.

Vibration enhanced the density separation by gravity settling. During the course of studying the effectiveness of vibration (including ultrasonic vibration), ultrasonic vibration alone (i.e., without floating the plastic in a liquid) appeared to cause segregation of the Type V waste. A dark band could be formed in Type V waste immersed in water inside a test tube using ultrasonic vibration by the proper selection of frequency and power. This could be duplicated without immersion in water but was more difficult. The dark band was thought to be paint separating from the plastic. One explanation for this phenomena was that the ultrasonic vibration fluidized the particle bed, allowing the denser paint particles to migrate to the bottom. (This explanation assumes that the paint is deagglomerated from the plastic and moves independently of the plastic.) One problem with this explanation was that the dark band did not form at the bottom but at about a third or a fourth of the bed height up from the bottom. Inspection of the product indicates that the product is segregating according to size, not density, implying more of a settling or packing phenomena. These results do not definitively prove ultrasonic vibration will not work in the manner suggested, but the results were discouraging enough that the limited resources of the project were concentrated on other areas. The principle of fluidizing the bed is sound (which should be achievable with ultrasonics), but the paint probably needs deagglomerating from the plastic, and even then the size of the paint particles will be important, for example, gravity forces may be swamped by electromagnetic forces (adhesive forces, van der Waals forces, etc.) if the particles are tiny enough. A fluidized bed was also discussed but not tested during Phase II (it was tested in Phase I with negative results). Once again, deagglomeration would likely have been needed and there is a likely competing effect, with the higher paint density providing a stronger downward force than the plastic, but the size and shape of the paint flakes perhaps giving a stronger drag force up than the plastic particles.

## 5.3 ANALYTICAL RESULTS

### 5.3.1 Total Metals Analysis

Table 3 lists the total metals analyzed by EPA Methods 3050 and 6010 to be in the Type V waste, Type II waste, the fractions from the large batch density separation of Type V waste using a  $\text{K}_2\text{CO}_3$  solution (1.28 kg/L), and Type II waste after ashing at 600°C. Table 4 lists the total metals analysis by Paar bomb combustion (ASTM-D3761), dissolution of the ash, and analysis of the extract by EPA Method 6010 (ICP).

### 5.3.2 Toxicity Characteristic Leaching Procedure

Table 5 lists the TCLP extract concentrations for the Type II waste, the Type V waste, the clean fraction after the large batch density separation of Type V waste using a  $\text{K}_2\text{CO}_3$  solution

**Table 3. Total metals analysis by direct extraction of solids (EPA Method 3050) and ICP analysis of the extract or solution (EPA Method 6010)**

Metal	Type II waste (mg/kg)	Type V waste (mg/kg)	After density separation of Type V waste using $K_2CO_3$			Type II ash (mg/kg)
			Clean (mg/kg)	Dirty (mg/kg)	Sol'n (mg/L)	
Barium	7100	1600	1300	6800	8.7	3200
Cadmium	140	27	21	110	0.75	1200
Chromium	1300	1000	180	1200	390	11000
Lead	540	1200	470	2600	240	5200
Arsenic	<5.4	<5.2	<5.2			
Selenium	<5.4	5.9	<5.2			
Silver	<0.64	<0.62	0.63			
Nickel	5.0	5.3	3.5			

**Table 4. Total metals analysis using the Paar bomb**

Metal (mg/kg)	Type II waste (mg/kg)	Type V waste (mg/kg)	After density separation of Type V waste using $K_2CO_3$		
			Clean (mg/kg)	Dirty (mg/kg)	Type V ash (mg/kg)
Barium	8400	660	1100	4200	12000
Cadmium	49	11	6.7	56	70
Chromium	490	150	230	280	1100
Lead	180	370	190	1100	7700
Arsenic	<0.64	<1.0	<1.0	<1.0	<1.3
Selenium	<0.64	<1.0	<1.0	<1.0	<1.3
Silver	<1.5	<1.5	<1.2	1.7	3.1
Nickel	150	32	79	78	450

Table 5. TCLP extract concentrations of the treated and untreated PMB wastes, mg/L

Sample	Barium	Cadmium	Chromium	Lead
Type II waste	1.5	2	29	0.08
Type V waste	1.5	0.83	19	0.07
"Clean" Type V waste after density separation using K <sub>2</sub> CO <sub>3</sub> solution	36	0.47	1.7	9.5
Self-encapsulated Type V waste pellet	1	0.26	2.7	0.82
Type II waste encapsulated in Type V waste pellet II:V ratio of 1:3	0.91	1.4	4.5	2.3
Type II cementitious waste form	1.1	0.01	<0.01	<0.05
Type V cementitious waste form	1.1	0.009	<0.01	<0.05
TCLP Limit	100	1	5	5

(1.28 kg/L), the self-encapsulated Type V pellets, the pellets of Type II waste encapsulated in Type V waste at a ratio of II:V of 1:3, and the cementitious waste forms of both Types II and V waste.

## 6. DISCUSSION

### 6.1 CHARACTERIZATION

Figures 3 and 4 illustrate the significant difference between the two analytical techniques for the total metals concentrations of the same samples. In general, EPA Method 3050 gave higher concentrations than the Paar bomb, the notable exceptions being the nickel analyses and the barium analysis for the Type II waste. The original reason for using the Paar bomb was because the plastic resists total destruction by EPA Method 3050, and the Paar bomb offered a way to remove the organic matter in a closed container (to prevent loss of the metallic species); that is, it was expected to yield more accurate values for the total metals content. These results indicate that although EPA method 3050 may not have extracted 100% of the metals in the plastic samples, it usually extracted more than the Paar analysis. Nickel was the only metal more efficiently extracted by Paar. Figure 3 clearly illustrates that barium, cadmium, chromium, and lead were the metals of concern for TCLP testing, with cadmium being an order of magnitude or more lower in concentration in the waste than the other three.

### 6.2 DENSITY SEPARATION

Figure 4 illustrates the much lower chromium and lead concentrations found in the light fraction after density separation using a  $K_2CO_3$  solution, apparently verifying the qualitative and subjective observations of successful density separation. However, these quantitative results prove that most of the chromium and lead were extracted into solution rather than being separated, with the large paint flakes falling to the bottom. Figure 5 illustrates the distribution of these metals (based on the EPA Method 3050 total metals analysis) after the large batch density separation, in which 98.5 wt% of the Type V waste was skimmed from the top of the solution and 1.5 wt% fell to the bottom or was suspended in the solution. As the total metals analysis indicated, 77 wt % of the chromium and 44 wt% of the lead was extracted into the  $K_2CO_3$  solution. Of the remainder, 92 wt% of the barium, 88 wt% of the cadmium, 21 wt% of the chromium, and 51 wt% of the lead was left in the light, supposedly "clean" fraction, leaving only 2, 4, 7, and 7 wt% of chromium, lead, barium, and cadmium, respectively, collected in the heavy fraction that separated from the bulk of the plastic. The photomicrographs clearly illustrated that this heavy fraction is mainly paint flakes, but apparently only a fraction of the paint deagglomerated and separated from the plastic. Extraction of chromium and lead into the solution was more efficient than density separation in cleaning the plastic.

### 6.3 TOXICITY CHARACTERISTIC LEACHING PROCEDURE PERFORMANCE

Figure 6 illustrates the TCLP extract concentrations compared to the TCLP limits. Note that the TCLP extract of the Type V waste exceeded the TCLP limit only for chromium and that the extract of the Type II waste exceeded the limit for chromium and cadmium. The lead concentration was about two orders of magnitude below the TCLP limit for the extracts of both Type II and V waste. Sometimes it is more informative to calculate the percentage of the total metal extracted during the TCLP test. Figure 7 illustrates the percent extracted for the TCLP

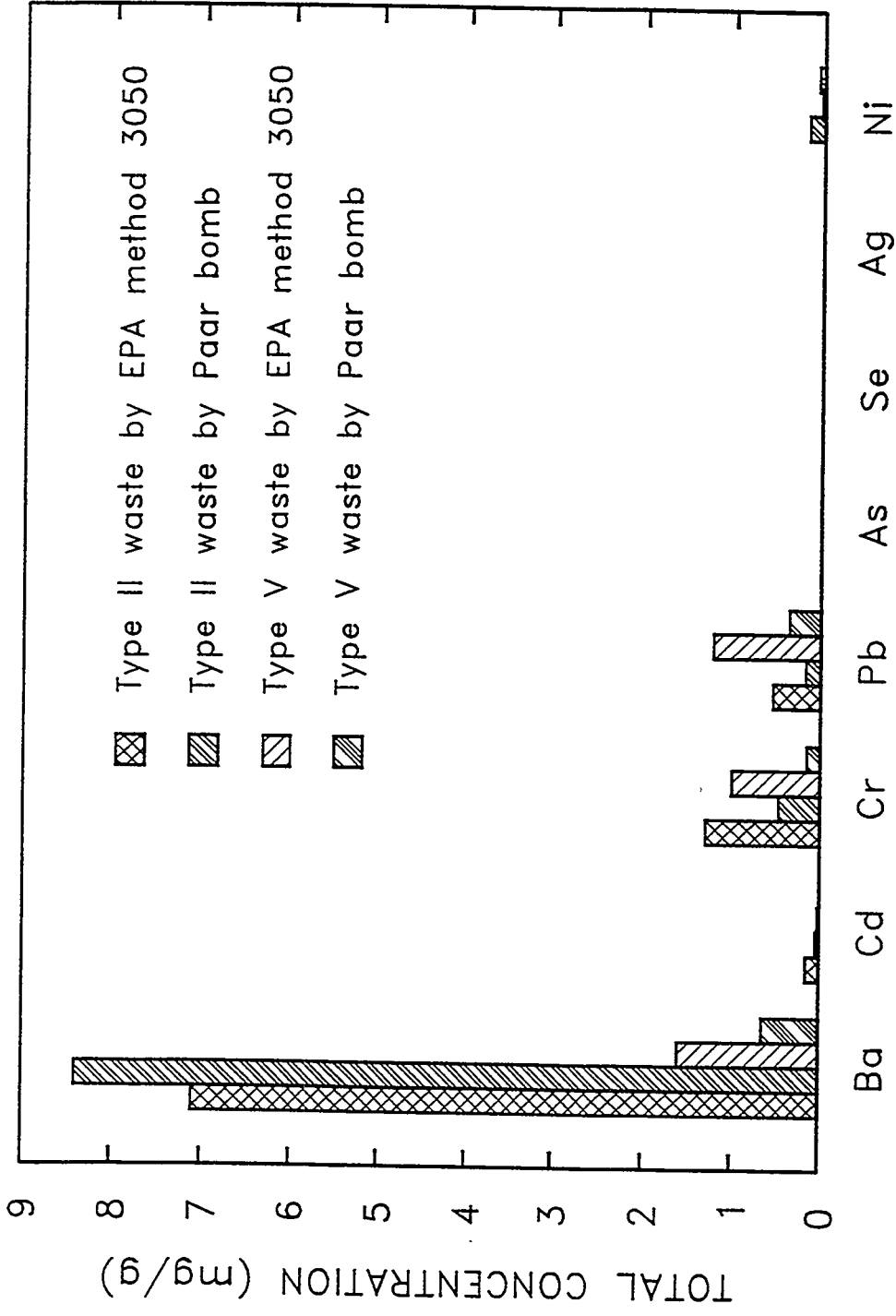


Fig. 3. Total concentrations of the metals in the Types II and V PMB waste using EPA Method 3050 and a Paar bomb.

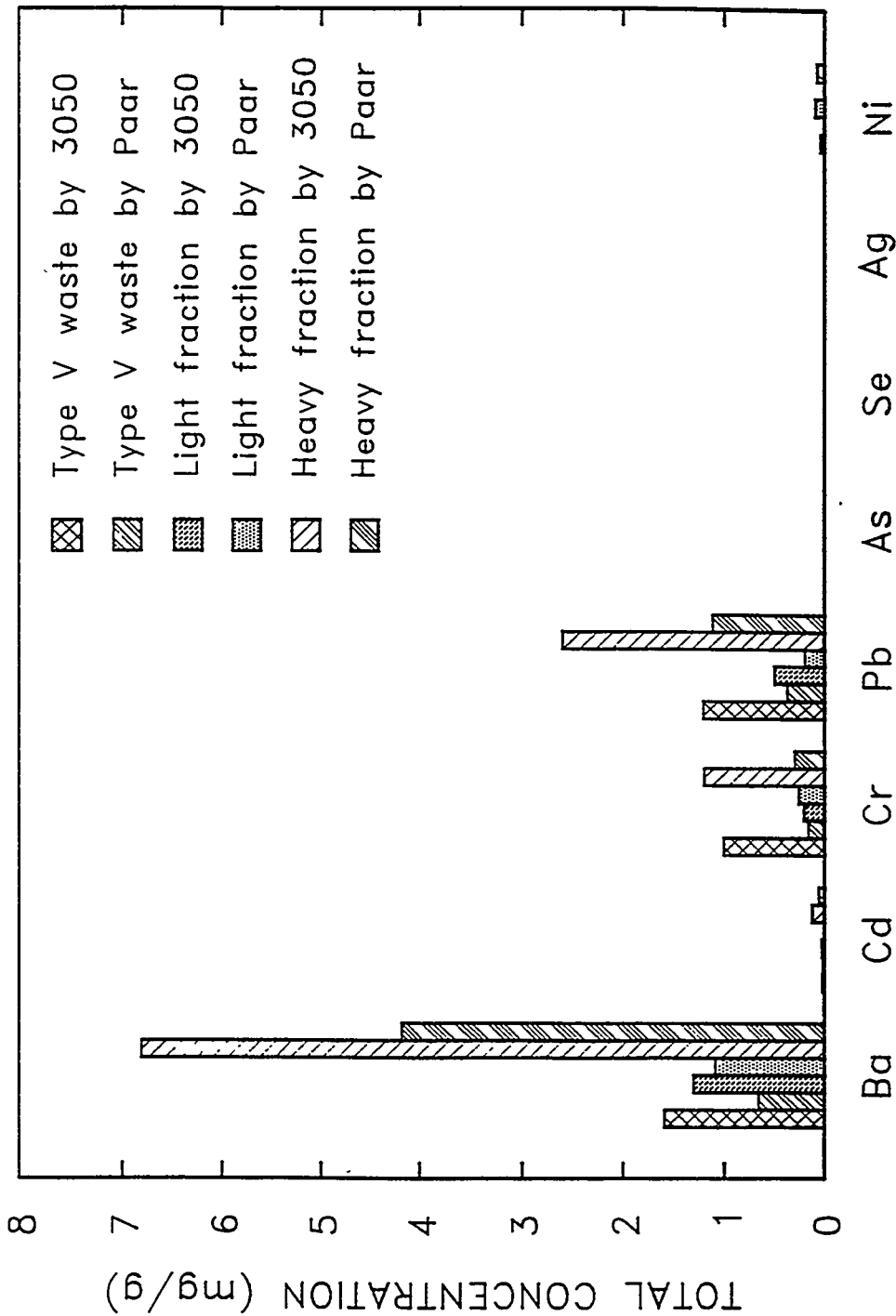


Fig. 4. Total concentrations of the metals in the Type V PMB waste before and after density separation in a  $K_2CO_3$  solution.

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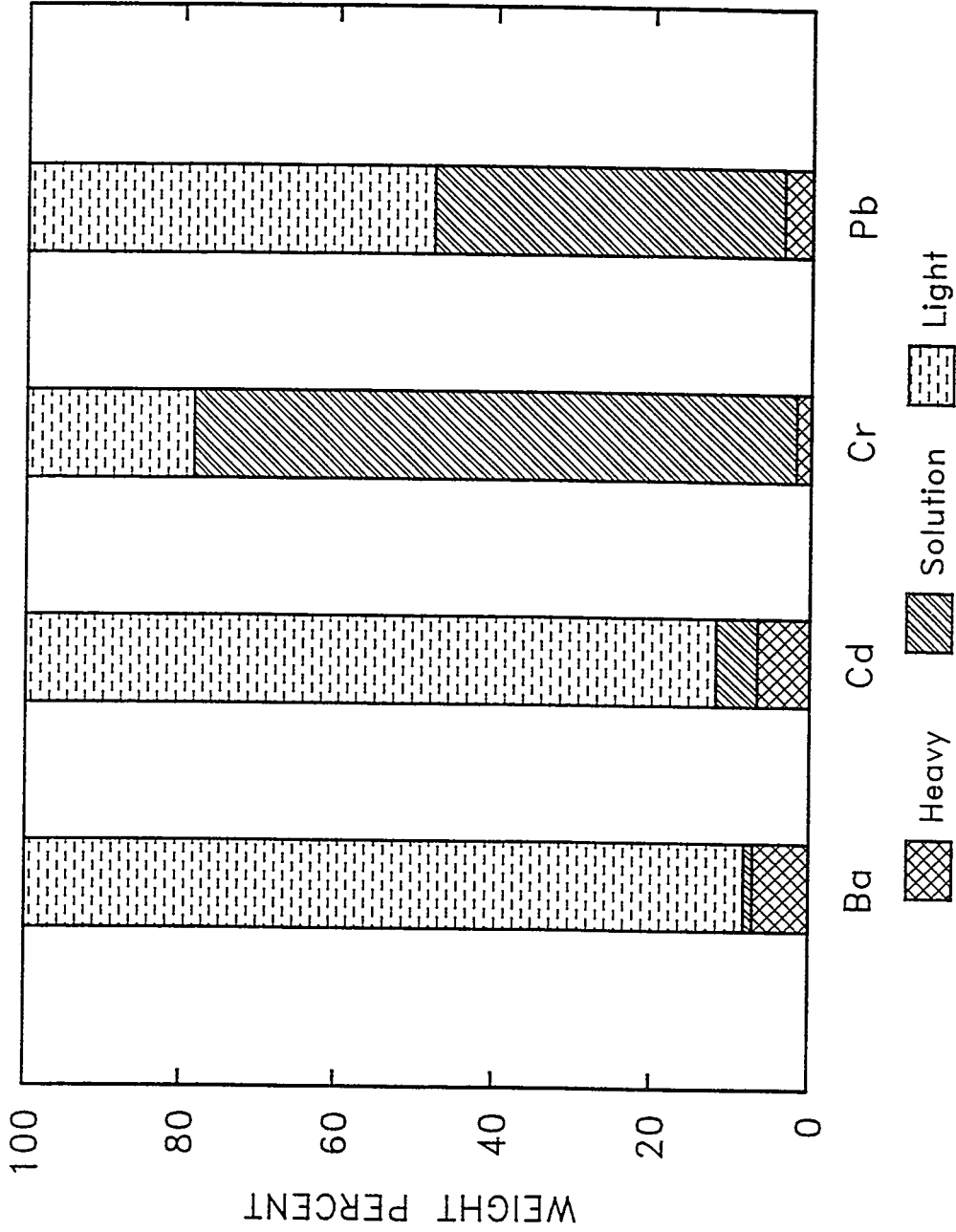


Fig. 5. Mass balance for the density separation of the Type V PMB waste using a  $K_2CO_3$  solution (based on the EPA Method 3050 analysis).

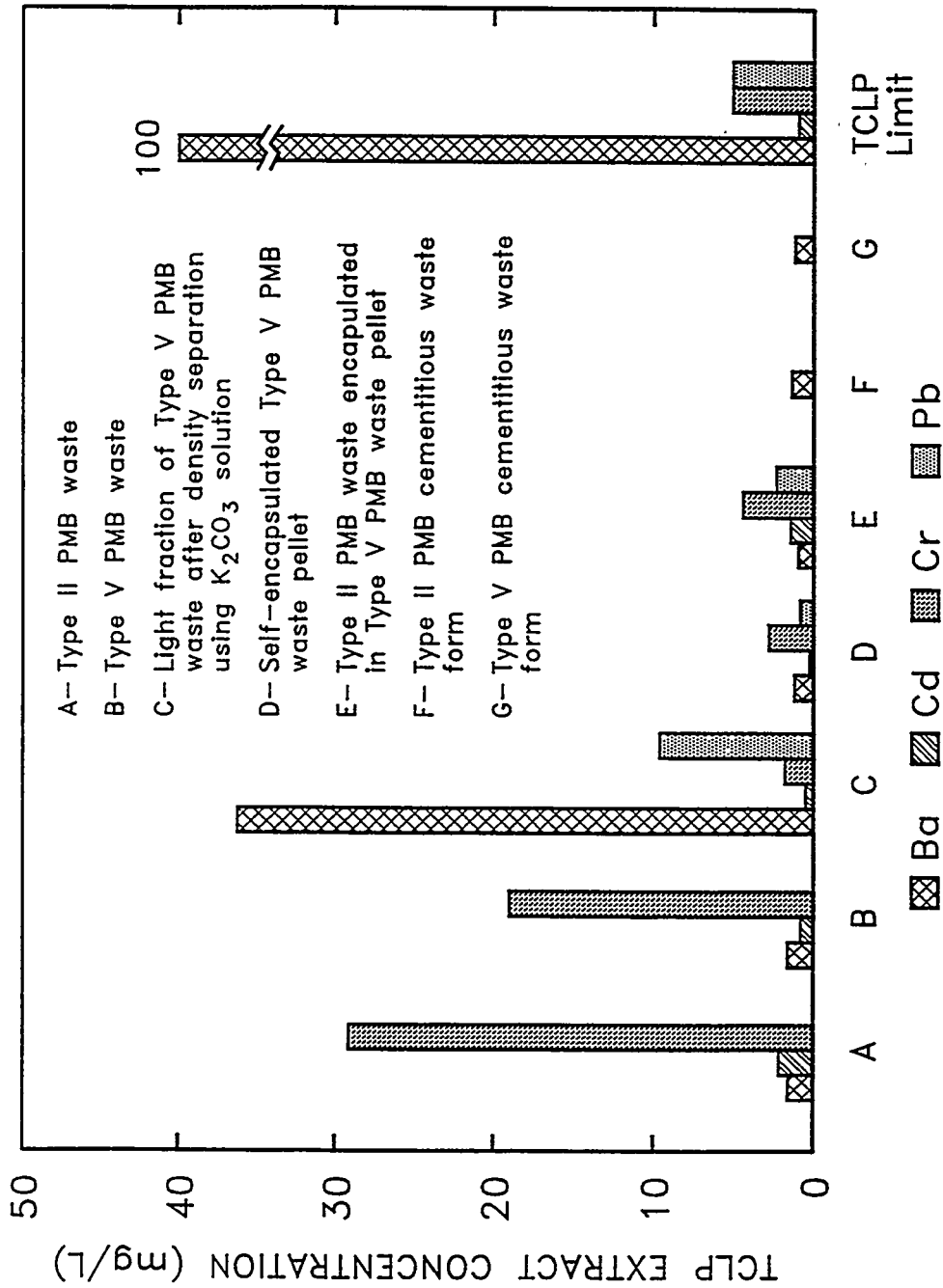


Fig. 6. TCLP extract concentrations of the RCRA metals before and after treatment of the Types II and V PMB wastes.

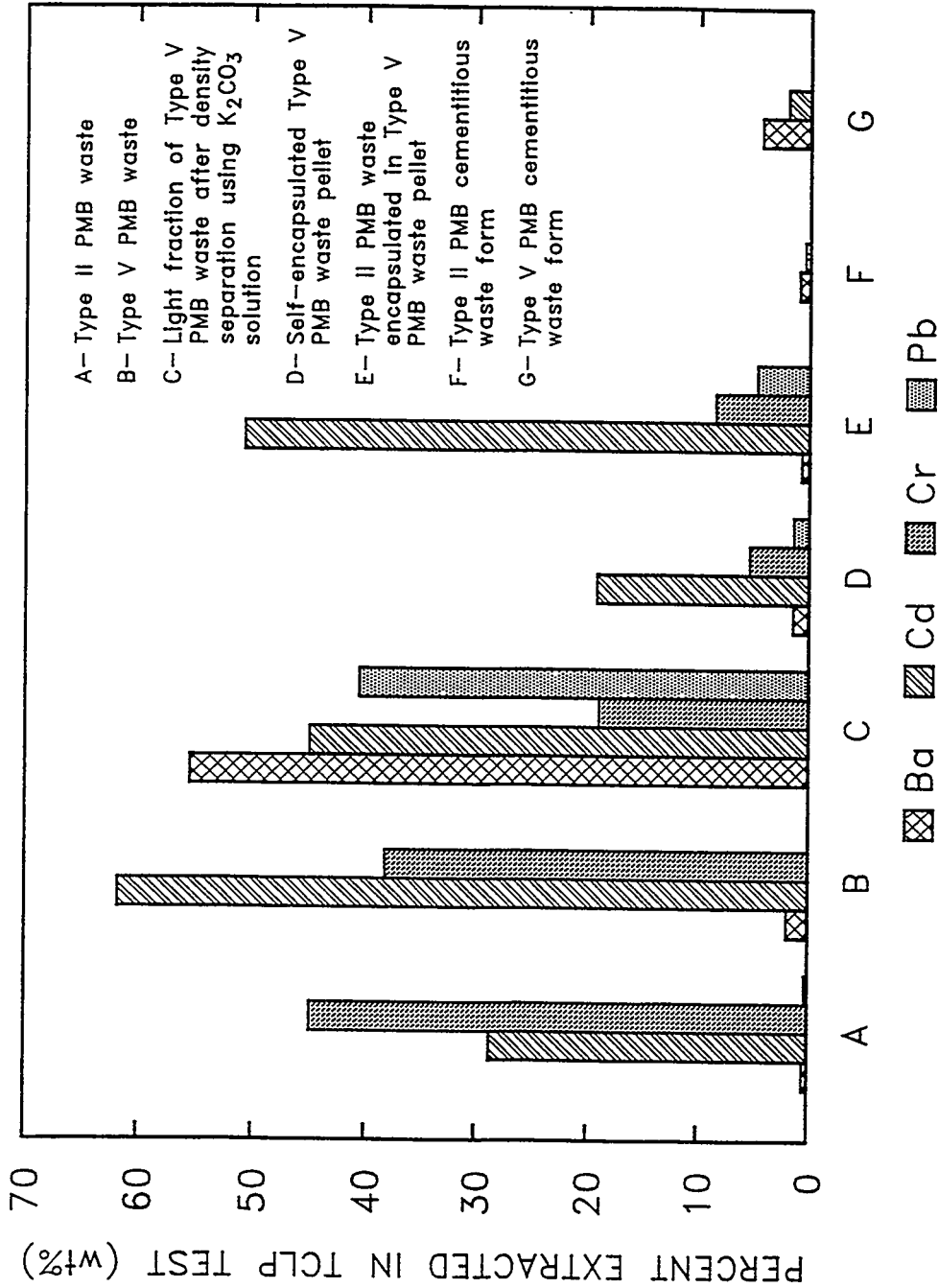


Fig. 7. Percentage of the total metal (based on EPA Method 3050 analysis) extracted during the TCLP extraction.

extracts presented in Fig. 6 based on the total metals analysis by EPA Method 3050 (Figs. 3 and 4). In general, TCLP extraction is done on a 100-g sample using 2 L (after final dilution) of extract (i.e., the calculated percent extracted is based on these two constants and the measured concentrations).

### 6.3.1 Density Separation

The density separation of the Type V waste lowered the chromium extract concentration of the light fraction below the limit (admittedly by extracting into the  $K_2CO_3$  solution), but, surprisingly, the lead concentration increased by two orders of magnitude and exceeded the limit. Figure 8 illustrates that the  $K_2CO_3$  solution also exceeded the TCLP limits for chromium and lead after this density separation. Summarizing, density separation of the Type V waste with a  $K_2CO_3$  solution took a solid waste characteristically hazardous with chromium and created a light solid fraction characteristically hazardous with lead, a solution characteristically hazardous with chromium and lead, and a heavy fraction undoubtedly characteristically hazardous (perhaps for all four metals). Apparently, the caustic solution (pH of 12) attacked the paint binder, helping in extraction of chromium and lead into the  $K_2CO_3$  solution and leaving the solid product more vulnerable to extraction in the TCLP test. These results need to be confirmed to ensure that an anomalous result does not cause an unnecessary redirection of this project. Despite these negative results, it still may be possible to develop a working density separation technique, if this is desired. Obviously, a driving force exists for paint to separate at the density used. Perhaps a less aggressive solution (lower pH) might work. Probably more aggressive pretreatment (e.g., surfactant, shearing, charring) to deagglomerate the paint would be required. Also, the bulk of the paint appears not to be the large flakes that were separated. If most of the paint consists of small particles, then a higher accelerating force (e.g., centrifuging) than gravity may be required to separate the paint. The terminal velocities of small particles are low for the density differences and solution viscosities being proposed. This implies that prohibitively long times may be needed to separate paint from the plastic, even if the driving force for separation exists and the paint is deagglomerated from the plastic. In addition, any aqueous solution used for density separation will likely extract chromium, which is soluble in the chromium (VI) valence state, and perhaps some lead, unless the solution is chemically altered to prevent this (e.g., adding reducing agents). Another alternative is to try organic liquids again. These were purposely avoided during Phase II because the organic liquids with the required density are usually halogenated organics and pose an additional environmental risk to the operation. Thus, although density separation may work, it needs more development prior to scaleup, and it may not be the simple operation once envisioned.

### 6.3.2 Encapsulation in the Type V Polymer

The results from the large batch density separation should not overshadow the fact that other options are available to treat and dispose of the PMB waste. Figure 6 illustrates that the self-encapsulated pellet of Type V waste passes the TCLP test. The encapsulation of Type II waste in Type V waste at a ratio of 1:3 was characteristically hazardous with cadmium but not chromium (although the chromium limit was close). About half the pellets made at this ratio were cracking circumferentially. These two results indicate that the amount of Type II waste needs to be decreased relative to the amount of Type V waste. This is a viable option for field application because both Hill AFB and McClelland AFB indicate that the use of Type II has declined and that mainly Type V is being used. This implies that little Type II waste is currently being

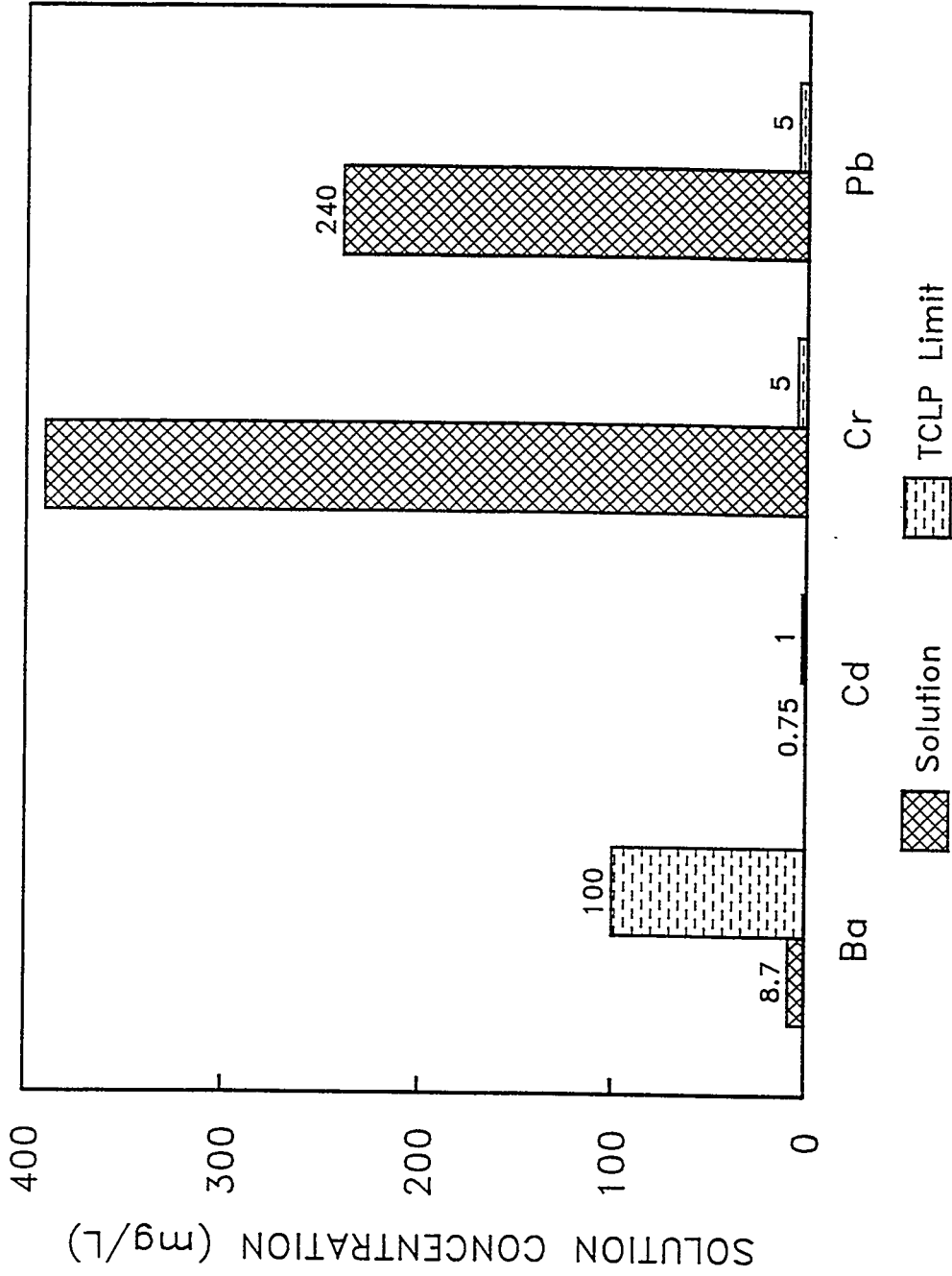


Fig. 8. Concentrations of the RCRA metals in the  $K_2CO_3$  after density separation of the Type V PMB waste compared to the TCLP limits.

generated. The current ratio of Type II waste to Type V waste is not known, but it may be possible to dispose of both by encapsulating the Type II waste in the Type V waste, if a ratio close to or better than the current ratio can be demonstrated to pass the TCLP test in the laboratory test. If not, then Type V virgin material might be used to help encapsulate the Type II waste.

The Type V waste contained relatively low levels of cadmium, and though most of it was extracted during the TCLP extraction, the extract concentration was below the TCLP limit. A smaller percentage of cadmium was extracted from the Type II waste, but this waste contained higher levels of cadmium than the Type V waste, and its TCLP extract concentration did exceed the limit. Around 40% of the chromium was extracted in both cases, exceeding the TCLP limit in both cases. Not much of the barium or lead was extracted in either case, resulting in TCLP extract concentrations well below the limits.

Figure 7 illustrates a decrease in the TCLP extractability of chromium and cadmium by self-encapsulating (pellets) the Type V waste. The barium extractability remained about the same, and the lead increased by an order of magnitude. Encapsulating the Type II waste in the Type V waste (at a II:V ratio of 1:3) resulted in a TCLP extractability for barium and cadmium intermediate between each of the wastes alone, before encapsulation. The chromium extractability decreased by a factor of 5, and the lead extractability increased by a factor of 5-10. The Type V pellet passed the TCLP test despite the increase in lead extraction, and the Type II:V pellet failed the cadmium limit and came close to failing the lead limit. These results were encouraging, and it was believed that a lower Type II waste amount relative to the Type V waste would have resulted in a pellet that would have passed the TCLP test. It was not clear why this encapsulation worsens the TCLP performance of lead, but the lowering of the chromium extract concentration below the TCLP limit was a significant improvement. It was possible that either the encapsulation process or the size reduction process for TCLP testing caused the higher extractability of lead. The size reduction requirement of the TCLP test does not give credit for the mass transfer barrier effect of making the PMB waste into monolithic pellets by encapsulation. Since the durability of these pellets was unknown, it cannot be proven how long this benefit would last, but the TCLP results indicate sufficient protection exists even if the Type V pellets do breakup with time.

### 6.3.3 Stabilization/Solidification

Stabilization/solidification (S/S) treatment can result in products that range from granular to monolithic. This technology is the "best demonstrated available technology" (BDAT) for metals disposal since the metals cannot be destroyed (as organics are in incineration). This technology has been successful in treating paints and paint pigments in the past. The PMB waste was mixed and hardened into a cementitious waste form. The Type II waste form did swell slightly, perhaps from water sorption of the thermoset resin. The cementitious waste forms stabilized the RCRA metals best of the treatments tested, based on the TCLP performance. This option offers the best hope of a quick response to the problem in the short term because it is accepted by the regulatory community. The other options will require development and proof that they work as well as the BDAT. Stabilization/solidification is essentially off-the-shelf technology with only tailoring of a formulation for the particular waste stream required. The volume increase resulting from S/S makes it a less attractive alternative. The PMB waste stream, consisting mainly of the plastic dust, is quite voluminous before adding the cementitious additives. The desire to decrease

this waste stream volume and the encapsulation of so much innocuous plastic in S/S makes encapsulating in Type V waste and low-temperature ashing more attractive. The low-temperature ashing alternative combines the high-volume reduction of low-temperature ashing with the stabilization potential of S/S (by destroying the plastic and then stabilizing the resulting ash in cementitious waste forms).

### 6.3.4 Low-Temperature Ashing

Another option—low-temperature ashing of the PMB waste followed by S/S of the ash—offers the following advantages favored by the regulatory community: (1) destruction of the bulk of the mass of the waste, (2) volume minimization by ashing, (3) S/S of the ash to immobilize the metals, and (4) a net volume decrease from the original waste instead of the volume increase usually associated with S/S. This option will require development and regulatory licensing. It usually takes years to obtain a license for a hazardous waste incinerator and has been a difficult task from a technical, legal, and regulatory standpoint. However, the low-temperature ashing does not require a hazardous waste incinerator because the intent of a hazardous waste incinerator is the total destruction of hazardous organics contaminating the waste, and the PMB waste was not contaminated with hazardous organics. The off-gas from the low-temperature ashing will have to be cleaned and an air discharge permit obtained. Undoubtedly, it will also be necessary to prove that no hazardous organics are produced and left in the ash. For example, if halogen compounds are introduced in any way, there is a danger of making hazardous compounds, such as dioxin, that may be left in the ash. Figure 9 illustrates the total metals analysis (both analytical techniques) of the ashes generated by ashing Type II and Type V waste. The mass remaining after ashing these two wastes at 600°C was 6.8 wt % for Type II waste and 1.7 wt % for Type V waste, fairly typical of other low-temperature ashing tests. Figures 10 and 11 illustrate the mass balance for the four main metals for these two low-temperature ashing tests based on the total metals analysis for both wastes and ashes. These results indicate that much of the metal initially in the plastic waste was lost during the ashing in the laboratory furnace. The paint pigments may decompose or disperse as a fine aerosol during the low-temperature ashing.

## 7. REVIEW OF OPTIONS

The options considered during this project were (1) density separation, (2) S/S of the current waste without pretreatment, (3) encapsulation in the Type V waste, (4) low-temperature ashing, and (5) recycle (not studied experimentally or previously mentioned in this report). This section will review the conceptual processes needed to implement each option, as currently visualized. These concepts may change as any given option is developed, but the intent is to give the reader the framework of reference used by the authors in applying these treatment options to the problem of handling the PMB waste stream. No detailed economic evaluation is presented, but some of the capital equipment thought needed is discussed in general terms. One of the important regulatory and economic considerations is the volume of waste to be ultimately landfilled for each option. A rough estimate of this was made based on our concept of each option and the laboratory results from this project and is presented in Table 6. The estimate will be better for some options than others but should be viewed as an order-of-magnitude estimate.

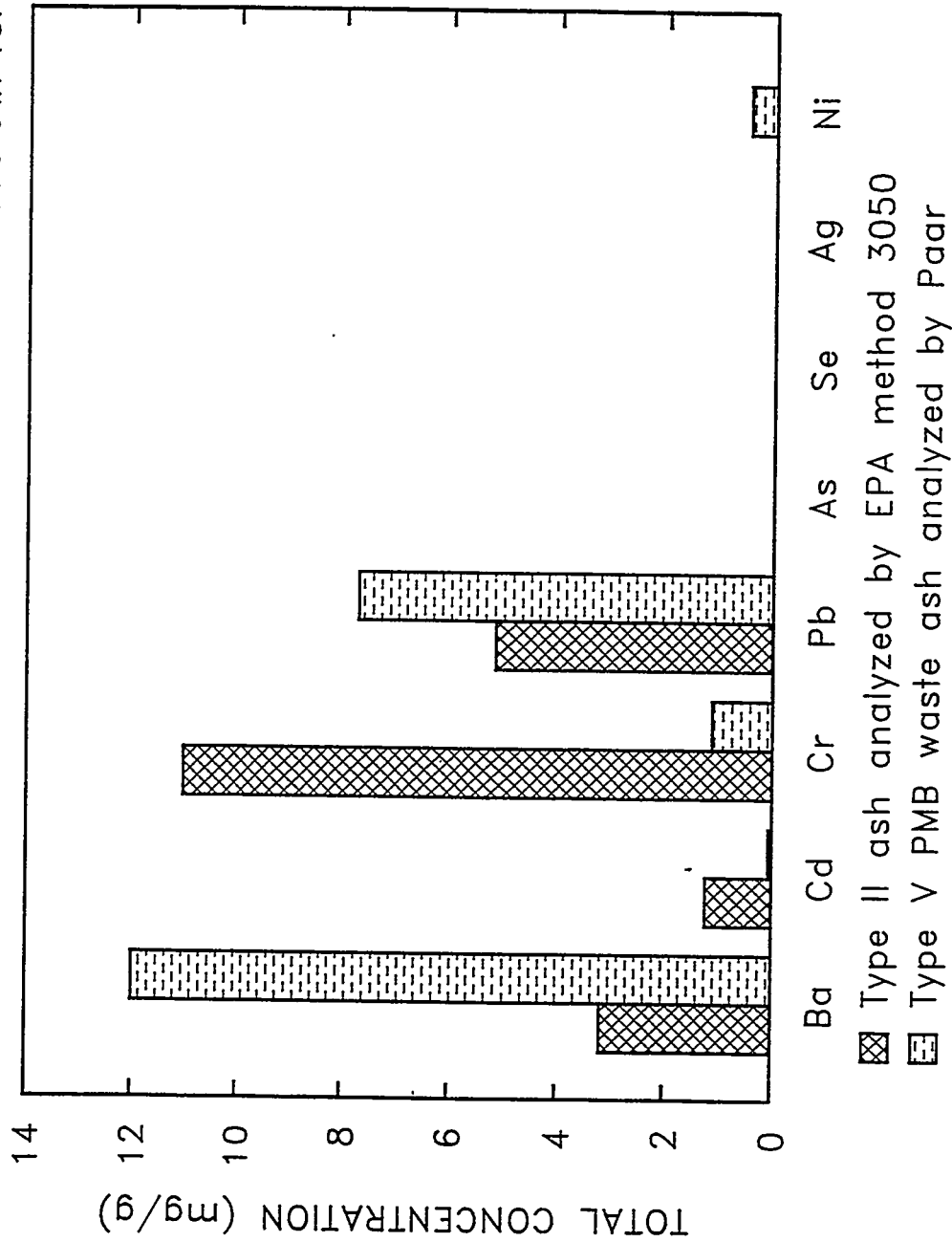


Fig. 9. Total concentrations of the metals in the ash of the PMB wastes ashed at 600°C.

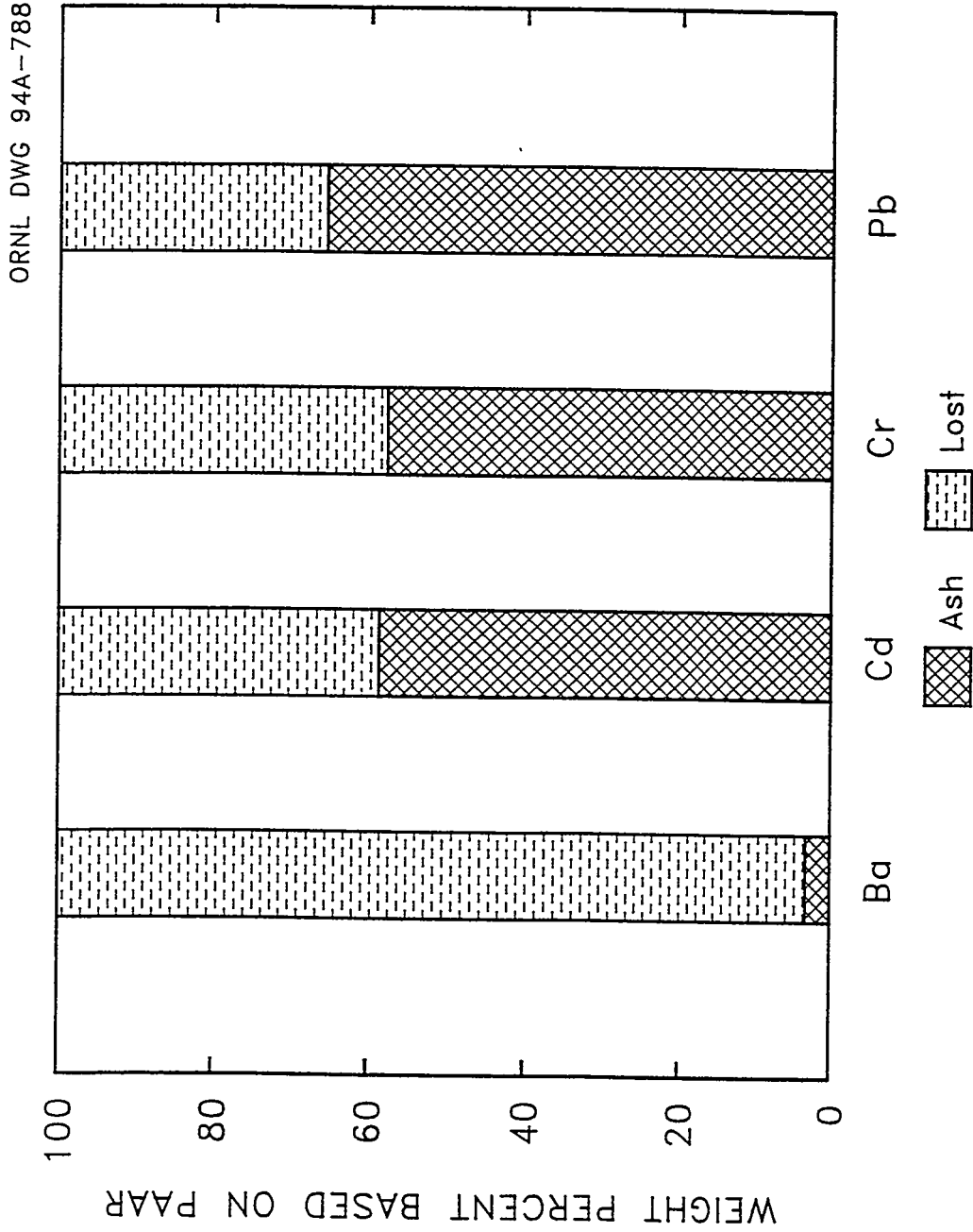


Fig. 10. Mass balance for the ashing of Type V PMB waste at 600°C (based on Paar).

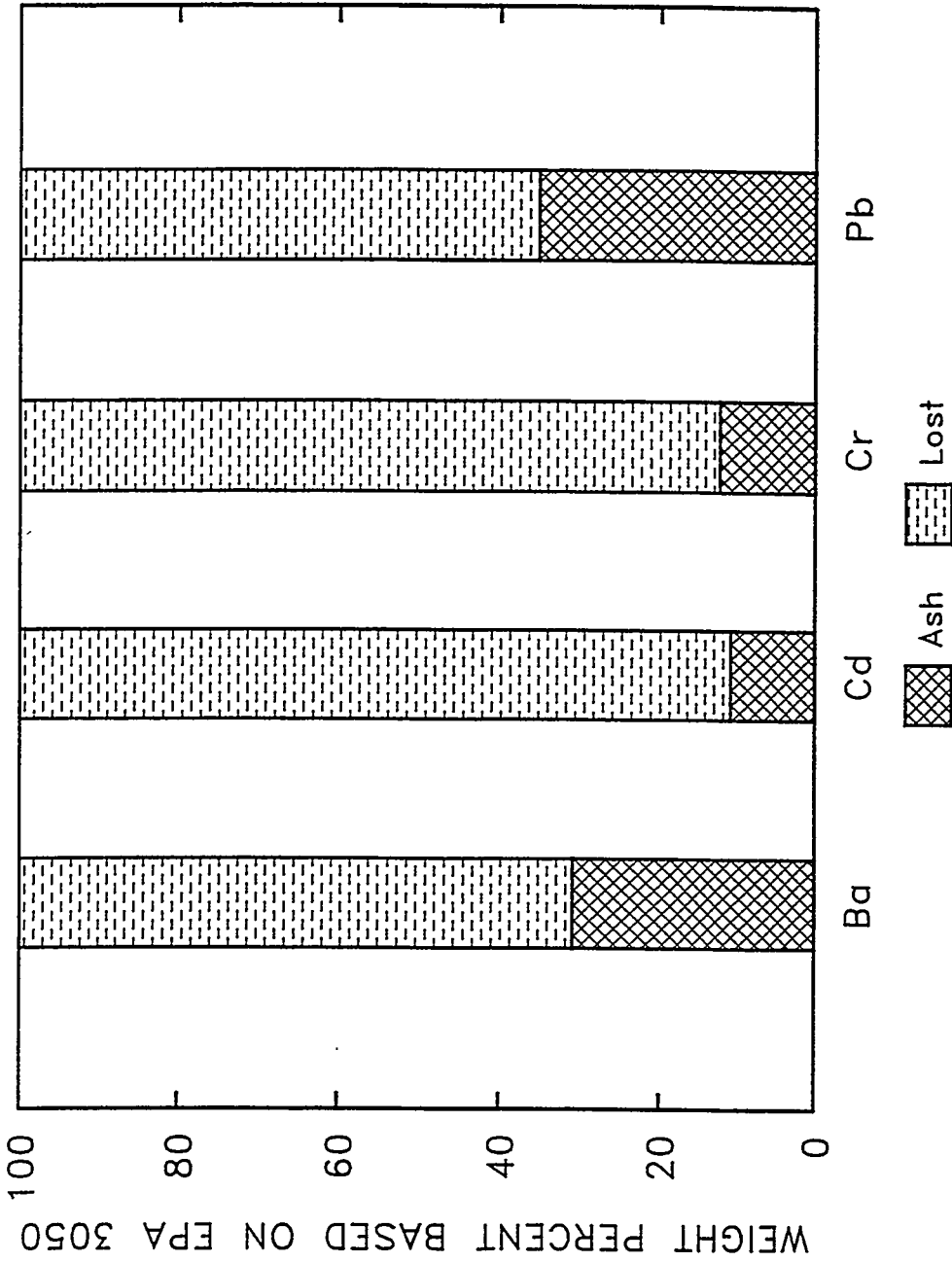


Fig. 11. Mass balance for the ashing of Type II PMB waste at 600°C (based on EPA Method 3050).

Table 6. Estimation of landfill volume relative to the initial PMB waste volume<sup>a</sup>

Option	Assumptions	Estimated ratio of nonhazardous landfill volume to initial PMB waste volume
1. Density separation	80 vol% of waste cleaned and landfilled  No net extraction of metals into the density separation medium  20 vol% of waste treated by S/S and landfilled  33 wt % waste loading in S/S waste form  Same density as in cement waste forms above	II:1.14 V:1.08
2. S/S of original waste	33 wt % waste loadings in S/S waste form  Same density as in cement waste forms above	II:1.68 V:1.42
3. Encapsulation in Type V waste	II:V ratio of 1:10  Same bulk density as pellet above	0.49
4. Low-temperature ashing	6.8 wt % ash from Type II waste and 1.7 wt % ash from Type V waste  S/S treatment of ash  S/S doubles the bulk volume of the ash  Ash bulk density of 0.5 kg/L	II:0.22 V:0.04
5. Recycle	All of the plastic are recycled  All of the paint pigments are recycled	0.00 <sup>b</sup>

<sup>a</sup>Bulk volumes: Waste—Type II 0.82 kg/L, Type V 0.64 kg/L; Pellet—1.34 kg/L; Cementitious Waste Form—Type II 1.46 kg/L, Type V 1.36 kg/L.

<sup>b</sup>Essentially for the original waste. The recycle process will undoubtedly generate liquid and gas waste streams, but not enough was known about how to recycle this waste to predict what the relative waste volume would be.

The density separation was originally envisioned as a small operation that fit in the current paint stripping operation and that would quickly and easily clean up the bulk of the plastic waste to a non-hazardous state (i.e., not characteristically hazardous by the TCLP test). The results from this project indicate that this separation will likely be neither quick nor easy. Table 6 assumed that density separation worked and that a finer density cut was needed to clean the plastic (hence the assumption of 20 vol% in the "dirty" fraction). Actually, a reproducible density separation technique must still be demonstrated on the laboratory scale. The final process, if it is developed, will likely include a pretreatment step such as shearing, charring, or both. It is likely that a surfactant will also be used. Since the product expected is a plastic waste with enough paint removed to pass the TCLP test, the light fraction may undergo a repeated cycling, for example, alternating steps of shearing and density separation. The results from this project imply that the bulk of the paint is finer than the plastic particles and that gravity settling alone will not work for large-scale cleanup of the plastic. The process steps for the bulk of the plastic were envisioned as drying and surface charring of the PMB waste, mixing and wetting (using a surfactant) the dry PMB waste with an aqueous salt solution, shearing the PMB waste slurry, density separation of the slurry by centrifuging (or gravity settling), repeating the shearing and density separation until the plastic is clean, filtering the cleaned plastic from the salt solution, rinsing any remaining salt solution from the cleaned plastic, drying the plastic, packaging the plastic, and landfilling the non-hazardous (TCLP criteria) plastic waste. The heavy fraction from the density separation (containing the hazardous metals) would be collected, filtered, mixed with binding agents into a grout, poured into the disposal container, cured, and landfilling as a non-hazardous waste form. The salt solution would be recycled, although some makeup would be needed to replace spills and losses with the exit streams. The intent was to use a salt solution in equilibrium with the metals in the waste so no net extraction of the metals will occur during steady state operation. It was assumed that this would not result in precipitation. If precipitation did occur, then the metal content of the solution would have to be continuously monitored and adjusted to prevent precipitation, resulting in net extraction of metals from the waste. It was also intended that the rinse water would be added to the salt solution (e.g., to replace water lost through evaporation). Balancing the rinse water flow rate with the evaporation rate, loss rate, and makeup rate is unlikely to match exactly; thus, a density adjustment step (using an evaporator, for example) would be needed to maintain the target salt solution density. In addition, a wastewater treatment plant would be required to process any unavoidable spills or handle any discharges of the metal-laden salt solution. It may be possible to use excess rinse water and discharges of the salt solution to slurry and hydrate the grout. The waste-water treatment plant would generate solids or sludges that could be landfilled by S/S.

The S/S of the current PMB waste without pretreatment would be the simplest option. The process envisioned was blending of the dry PMB waste with the dry binding agents, mixing this dry blend with just enough water to make a workable paste, pouring this grout into the disposal container, curing until hardened, and landfilling the non-hazardous S/S treated waste. (Blending the PMB waste with the binding agent as a dry blend would be recommended as opposed to wet mixing the ingredients with water one at a time.) The solids handling, blending, and mixing equipment are readily available commercially at about any scale desired.

Encapsulation of the PMB waste offers a somewhat elegant solution in that no additional additives or agents would be needed. The waste would be rendered non-hazardous by using the properties of the PMMA readily available in the Type V waste. Not only should it be possible to self-encapsulate the Type V waste, but it should also be possible to encapsulate the Type II waste in the Type V waste. The process envisioned was mixing the Type II into the Type V, pre-drying of the PMB waste, loading into an extruder or heated mechanical press, heating and pressurizing, curing the softened PMMA at temperature and pressure (the soft PMMA would then either be extruded or cooled while maintaining the mechanical pressure) packaging the pellets, and landfilling the non-hazardous pellets.

Low-temperature ashing offers the opportunity to minimize the volume of the original waste and dispose of the resulting ash by the BDAT for metals disposal. The process envisioned was loading the original PMB waste either continuously (conveyor belt) or batchwise into a furnace, ashing at a low-temperature using temperature and air feed control (pyrolytic ashing, that is, without forced air feed, might be desirable to prevent air currents from generating aerosols), mixing the ash with binding agents and water, pouring the grout into the disposal container, curing it until hardening, and landfilling the non-hazardous S/S treated ash. The ashing will produce an off-gas containing combustion gases, pyrolytic products, and aerosols. The off-gas would exit the furnace; pass through a spray tower to trap acid gases and larger aerosols and cool the gas for bag filtration; efficiently filter out fine aerosols with bag filters; pass through an afterburner to efficiently combust incompletely burned gases; and finally discharge to the atmosphere. The trapped fly ash, bottom ash, and binder agent would be blended and then mixed with the slurry from the wet scrubber. Extra water would be added if needed for the hydration reactions to make the cementitious waste form. The afterburner may need to be located prior to the wet scrubber to combust organic pyrolytic products and prevent them from being trapped in the scrubber slurry or bag filter.

Recycle was the least developed option and was only discussed conceptually during the project, but it may become the regulatory goal in the future. The process envisioned was extraction of the metals, or separation of the paint, from the PMB waste. The clean plastic would be regenerated for PMB to strip paint from aircraft. (Clean Type II likely could not be recycled in this manner, but Type V could; hence, a corollary would be a total switch to Type V or other thermoplastics.) The extracted metals or separated paint would be recycled as paint or other uses. If extracted, the metals would be precipitated and the solution recycled as an extractant. The metals would be chemically recovered from the precipitated sludge or the sludge would be ashed and the metals recovered from the ash. If separated, the paint would most likely be ashed and the metals recovered from the ash. The density separation tests demonstrated that extraction of the chromium and some of the lead appears possible. More aggressive extraction would likely damage the plastic, perhaps making it unusable. On the other hand, separation appears to be difficult and the salt solutions used also appear to be chemically aggressive. In other words, the recycle of the plastic may not be economical and ashing the waste with recovery of the metals from the ash might be the best recycle option. A corollary of this option would be to substitute non-hazardous paints for the ones currently used on the aircraft. Once these paints replaced the hazardous paints already on the aircraft, the PMB waste would cease to be hazardous, although recycle of the plastic might still be a future goal.

The implementation of the land ban restrictions prevents the land disposal of RCRA hazardous waste, meaning treatment of the PMB waste is now required prior to land disposal. In addition, the current regulatory environment would likely require land disposal of even a treated waste in a monitored landfill unless it can be proven that the hazardous constituent is no longer present. Since the metals cannot be destroyed, cleaning the plastic would reduce the volume required to be monitored, and only recycle or replacement would possibly avoid such a requirement.

## 8. SUMMARY

- The Type V waste was characteristically hazardous by the TCLP test because of chromium, and Type II waste was characteristically hazardous because of chromium and cadmium.
- The lead TCLP extract concentration was two orders of magnitude below the TCLP limit for both PMB wastes, despite lead being one of the main metal contaminants.
- After density separation, the Type V waste was characteristically hazardous because of lead, but not chromium.
- Apparently, density separation of Type V waste with a  $K_2CO_3$  solution resulted in the removal of large flakes of paint that were a minor fraction of the total paint, extraction of most of the chromium and part of the lead, and a cleaner waste that was more extractable in the TCLP test.
- Self-encapsulation of the Type V waste resulted in a pellet that passed the TCLP test.
- The barium, cadmium, and chromium TCLP extract concentrations decreased after self-encapsulation, but the lead concentration increased by an order of magnitude, although it remained below the TCLP limit.
- Encapsulation of Type II waste in Type V waste at a II:V ratio of 1:3 resulted in a pellet that was characteristically hazardous because of cadmium.
- The percent extracted during the TCLP extraction decreased for chromium and barium by encapsulating Type II waste in Type V waste, was between that of Type II and V waste for cadmium, and increased for lead.
- The PMB waste ashes at 500–600°C, yielding about 5 wt % ash for Type II waste and about 2 wt % ash for Type V waste.
- The virgin Type II yielded about 2 wt % ash composed mainly of barium.
- The virgin Type V was almost ashless. Although the total mass was small, this ash was mainly silicon, with a significant relative amount of barium.
- Both PMB wastes hardened into cementitious waste forms at a waste loading of 33 wt % using GBFS, and slight swelling (about 3 vol %) of the Type II waste form was noted.

- The cementitious waste forms of both the Types II and V PMB waste gave the best TCLP performance of the samples tested and were an order of magnitude, or more, below the TCLP limits.

## 9. CONCLUSIONS AND RECOMMENDATIONS

It appears that density separation using salt solutions works on the larger paint particles that deagglomerate from the plastic; however, based on laboratory tests thus far, the bulk of the paint remains with the plastic. Even worse, the salt solution extracted enough chromium and lead to make it characteristically hazardous, and the treatment made the metals remaining in the plastic even more extractable. It would be wise to verify these results prior to making any final decisions. Chromium (VI) is soluble, so some extraction seems likely in any event, although reduction could be attempted as a pretreatment to limit this solubilization. The high pH was suspected of causing deterioration of the paint binder, leading to access to the lead and its subsequent extraction. Chemical alteration of the lead compound(s) may have also caused the observed mobilization of the lead. Although these results appear discouraging, they do indicate possible ways to improve density separation. A pretreatment such as charring and shearing might deagglomerate most of the paint, the higher acceleration of centrifuging might remove more of the small particles, recycling the plastic might remove most of the paint, recycling the salt solution might prevent net extraction of metals, and using another salt might prevent deterioration of the paint binder and/or mobilization of the lead. Even though density separation has not been definitively ruled out, it is obvious that more laboratory development is needed to even demonstrate its feasibility for this application; scaleup to an engineering demonstration must await this laboratory development; a density separation operation would be more complex than once envisioned; the separated paint would still be a RCRA waste and require treatment prior to its disposal even if density separation works; and the density separation solution would likely extract some metals (chromium, if nothing else), meaning chemical as well as density monitoring of the salt solution would likely be required and any discharges would require treatment.

The original intent of density separation was to concentrate the hazardous constituents into a much smaller waste stream, allowing the bulk of the plastic to be disposed as a non-hazardous waste while the smaller RCRA waste stream would have been disposed as the entire waste stream was at the beginning of the program. At this time, it is not apparent that this option is the best choice from either a technical or economic standpoint. For the short term, the USAF can likely obtain the quickest regulatory approval for treatment of the waste stream by S/S, the BDAT for metals. A S/S formulation could be tailored for this waste by either ORNL or any one of several vendors. Density separation might reduce the waste needing S/S. If separation is technically demonstrated, then an economic evaluation of all the options would indicate whether density separation would be favored.

Low-temperature ashing offers some long-term advantages, unless recycle is desired. First, the volume of the waste stream would be reduced to a minimum. Second, although regulatory approval would be required, the licensing procedure would not be the same one required for hazardous waste incineration of organic wastes. This waste is not hazardous with organics, so demonstration of 99.99% or 99.9999% destruction would not be necessary. Third, the ash could be treated by S/S, a demonstrated, commercially available technique. This option would require development of the ashing technique. There is likely no commercial furnaces available specifically

for this application, but commercial furnaces could likely be adapted if the operating parameters can be specified.

Encapsulation in the Type V waste offers an elegant solution to the problem in that no other materials need to be added. The equipment needed to heat and press the waste into pellets is all that would be required. It remains to be seen whether the regulatory agencies would accept this simple encapsulation treatment. Although it appears the product should pass the TCLP test at the right II:V ratio, it may be necessary to equal or surpass the BDAT treatment (S/S).

## 10. REFERENCES

1. R. E. Tapscott, G. A. Blahut, and S. H. Kellog, *Plastic Media Blasting Waste Treatments*, ESL-TR-88-12, July 1988.
2. J. E. Helt and N. Mallya, "Incineration Residue from Paint Stripping Operations Using Plastic Media Blasting," submitted to the Tenth Annual Industrial Energy Technology Conference in Houston, Texas, September 14-16, 1988, CONF-880982-4, DE89 005782.
3. MIL-P-85891(AS), Military Specification, "Plastic Media for Removal of Organic Coating," May 6, 1988.



**APPENDIXES**



## Appendix A. Analysis of Type V waste from McClelland AFB.

ANALYTICAL EVALUATION/TEST RESULTS  
 PHYSICAL SCIENCES LAB, McCLELLAN AFB, CA 95652-5990  
 TELEPHONE (916)643-6987

TO: MCBRIDE/ MAQV

FROM: MAQCB/3-6987

SUBJECT: PLASTIC MEDIA BLAST

TESTED BY: DOMEK/ SUGAR

DATE: 23 AUGUST 89

PROJECT NO. 89-740

DATE RECEIVED: 18 JULY 89

LAB NO.	MAQV#	TEST RESULTS			
501-89	9171	METALS ANALYSIS: ( RESULTS IN MG/ KG )			
		METAL:	RESULT:	METAL:	RESULT:
		HOLYBDENUM	< 2.2	IRON	2473.1
		CHROMIUM	2523.9	COBALT	17.0
		ANTIMONY	< 2.2	VANADIUM	< 2.2
		ZINC	156.0	BERYLLIUM	< 2.2
		CADMIUM	24.7	COPPER	25.8
		LEAD	1330.7	SILVER	< 2.2
		NICKEL	< 2.2	MANGANESE	34.0
		THALLIUM	< 2.2	ALUMINUM	437.6
				BARIUM	1793.6

8/23/89

NOTES: METALS ANALYSIS BY EPA METHOD 6010.

OFFICIAL SIGNATURE:

*William Jang*  
 CHEM SCIENCES SECTION  
 DIR. OF MAINTENANCE

REVIEWED BY: *J. O'Neil* 8/23/89

Subject 111-121-

*3-1-90 Hooper N. J.*

ANALYTICAL EVALUATION TEST RESULTS  
 PHYSICAL SCIENCES LAB, McCLELLAN AFB, CA 95652-5990  
 TELEPHONE (916) 643-6987

TO: MAQV / MCBRIDE  
 EMC

FROM: MAQCB/3-6987

SUBJECT: ANALYSIS OF POWDER FROM FMS  
 EQUIPMENT ROOM, BLDG. 692

TESTED BY: CHAPFELLE/SUGAR

DATE: 11 JUL 89

DATE SAMPLED: 29 JUN 89

PROJECT NO. 89-

LAB NO.	DESCRIPTION	TEST RESULTS		
423-89 <i>Free</i>	COLLECTOR'S NO. 9157 GREY-GREEN POWDER	METAL	STIC =g/L	TTLIC =g/kg
		BARIUM	15.01	331.15
		BERYLLIUM	0.01	< 0.35
		CADMIUM	0.82	21.47
		CHROMIUM	93.90	1139.00
		COBALT	< 0.06	69.50
		COPPER	0.21	26.56
		LEAD	10.62	650.49
		MOLYBDENUM	< 0.14	5.09
		NICKEL	0.07	2.18
		SILVER	< 0.02	< 0.73
		THALLIUM	< 1.66	< 60.41
		VANADIUM	< 0.02	< 0.73
ZINC	2.80	138.65		
424-89 <i>CC252</i>	COLLECTOR'S NO. 9158 GREY-GREEN POWDER	BARIUM	42.90	936.54
		BERYLLIUM	< 0.01	< 0.40
		CADMIUM	1.70	9.30
		CHROMIUM	76.60	1543.10
		COBALT	0.34	15.36
		COPPER	1.04	30.32
		LEAD	45.20	946.05
		MOLYBDENUM	< 0.14	< 5.66
		NICKEL	0.07	4.45
		SILVER	< 0.02	< 0.81
		THALLIUM	< 1.66	< 67.10
		VANADIUM	< 0.02	< 0.61
		ZINC	10.03	35.57

REMARKS: METALS ANALYZED BY ICP, USING EPA METHOD 6010. SAMPLES PREPARED BY EPA METHOD 8050. STIC ACCORDING TO TITLE 22.

OFFICIAL SIGNATURE

*W. D. Hooper*

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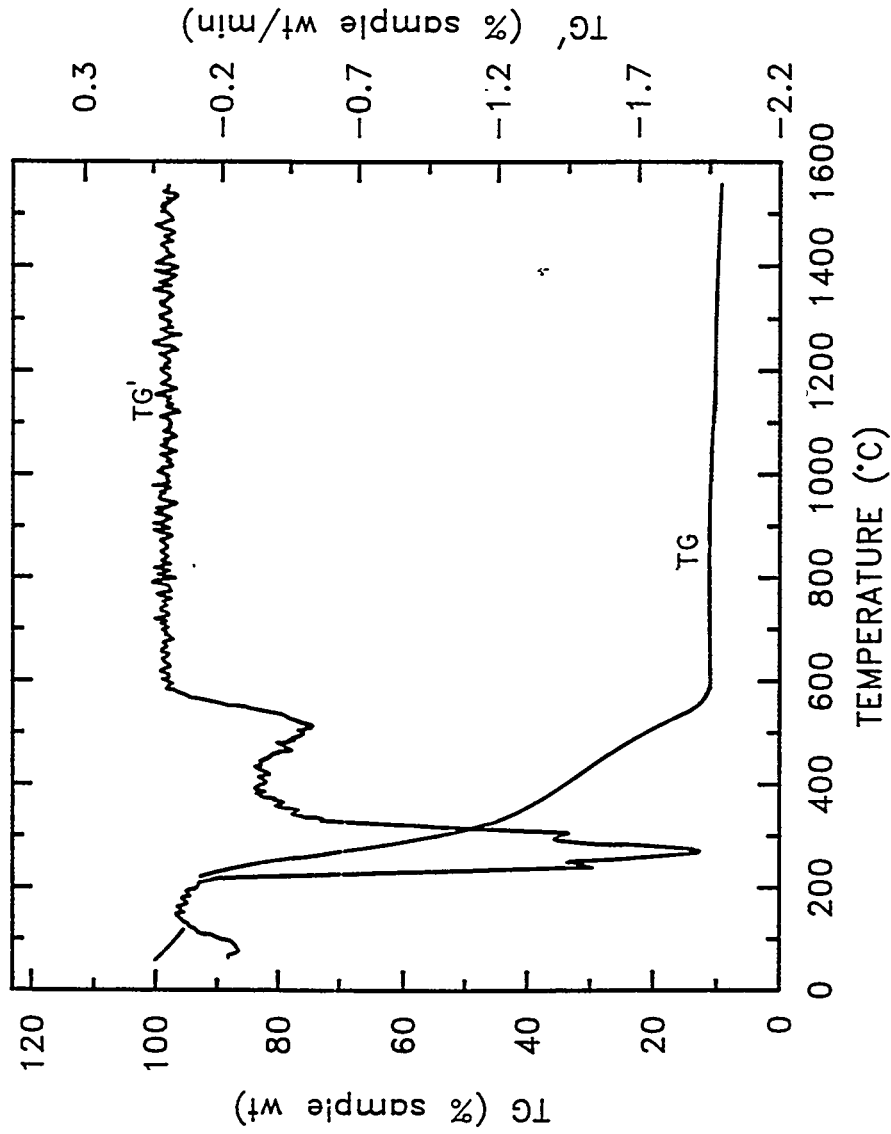
REVIEWED BY: *J. O. (7-11-89)*

Appendix B. Thermogravimetric analysis of PMB waste.

ORNL DWG 94A-790

Operator:	JSM	Netzsch Station No. 1	Atmosphere:	Air
Date:	17 Aug 1990	Reference: Alumina	Flow Rate, cc/min:	100
Run No.:	2	Crucible: Alumina	Heat Rate, °C/min:	3
Sample No.:	900801-072	Fill Name: Test: JSM003	Sample wt, mg:	50.5
Sample Name:	ASH	Lot No.: 3850-47-3	Reference wt, mg:	100

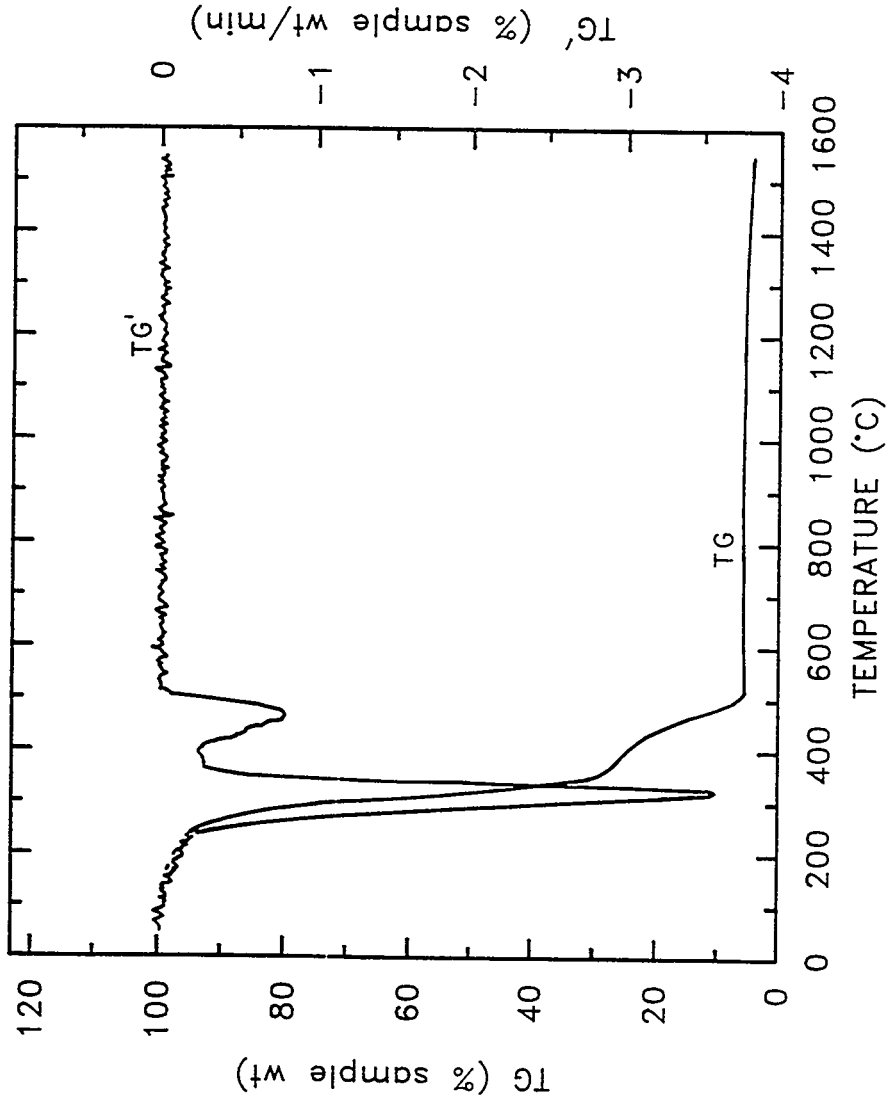
TYPE II WASTE



ORNL DWG 94A-791

Operator:	JSM	Netzsch Station No. 1-	Atmosphere:	Air
Date:	10 Aug 1990	Reference: Alumina	Flow Rate, cc/min:	100
Run No.:	2	Crucible: Alumina	Heat Rate, °C/min:	3
Sample No.:	900801-071	Fill Name: Test: JSM002	Sample wt, mg:	52.2
Sample Name:	ASH	Lot No.: 3B50-47-2	Reference wt, mg:	100

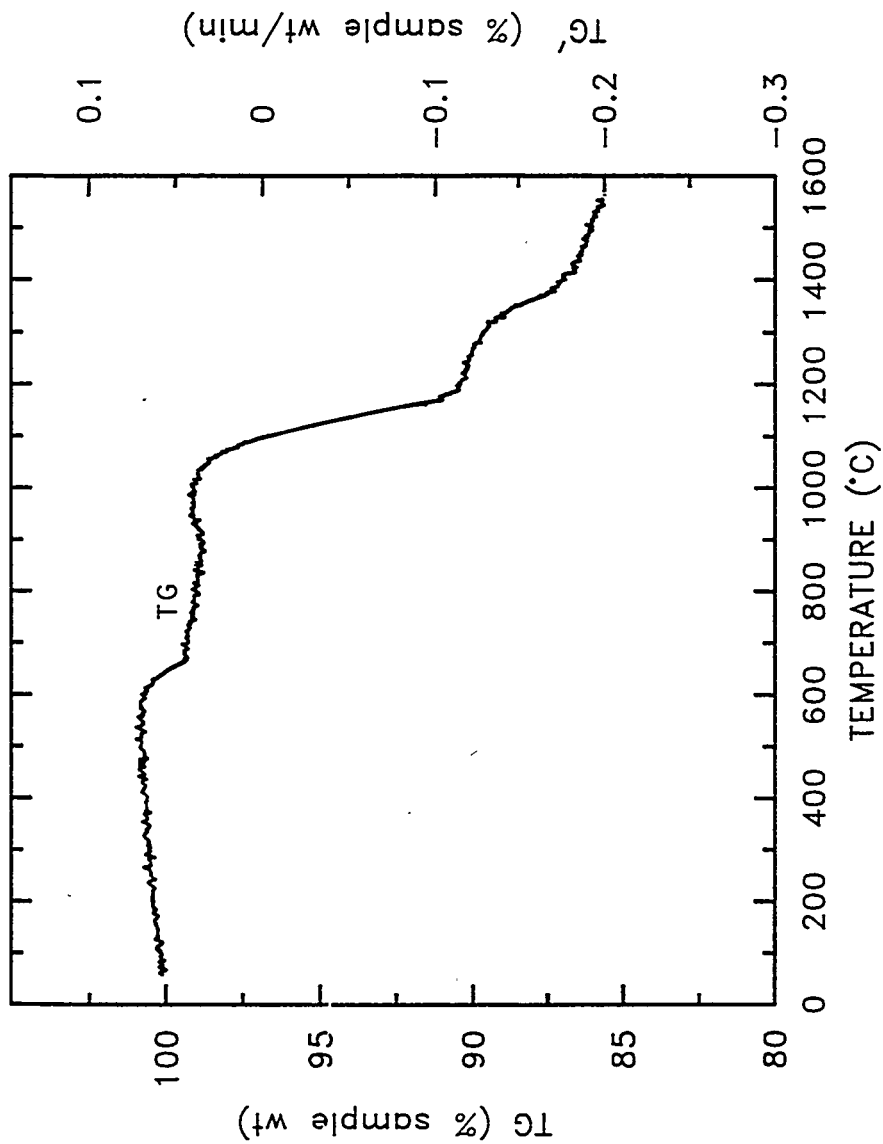
TYPE V WASTE



ORNL DWG 94A-792

Operator: JSM — Netzsch Station No. 1 — Atmosphere: Air  
 Date: 15 Aug 1990 Reference: Alumina Flow Rate, cc/min: 100  
 Run No.: 1 Crucible: Alumina Heat Rate, °C/min: 3  
 Sample No.: 900801-074 Fill Name: Test: JSM005 Sample wt, mg: 57.0  
 Sample Name: ASH Lot No.: 3850-47-5 Reference wt, mg: 100

TYPE II WASTE AFTER  
 ASHING AT 525°C



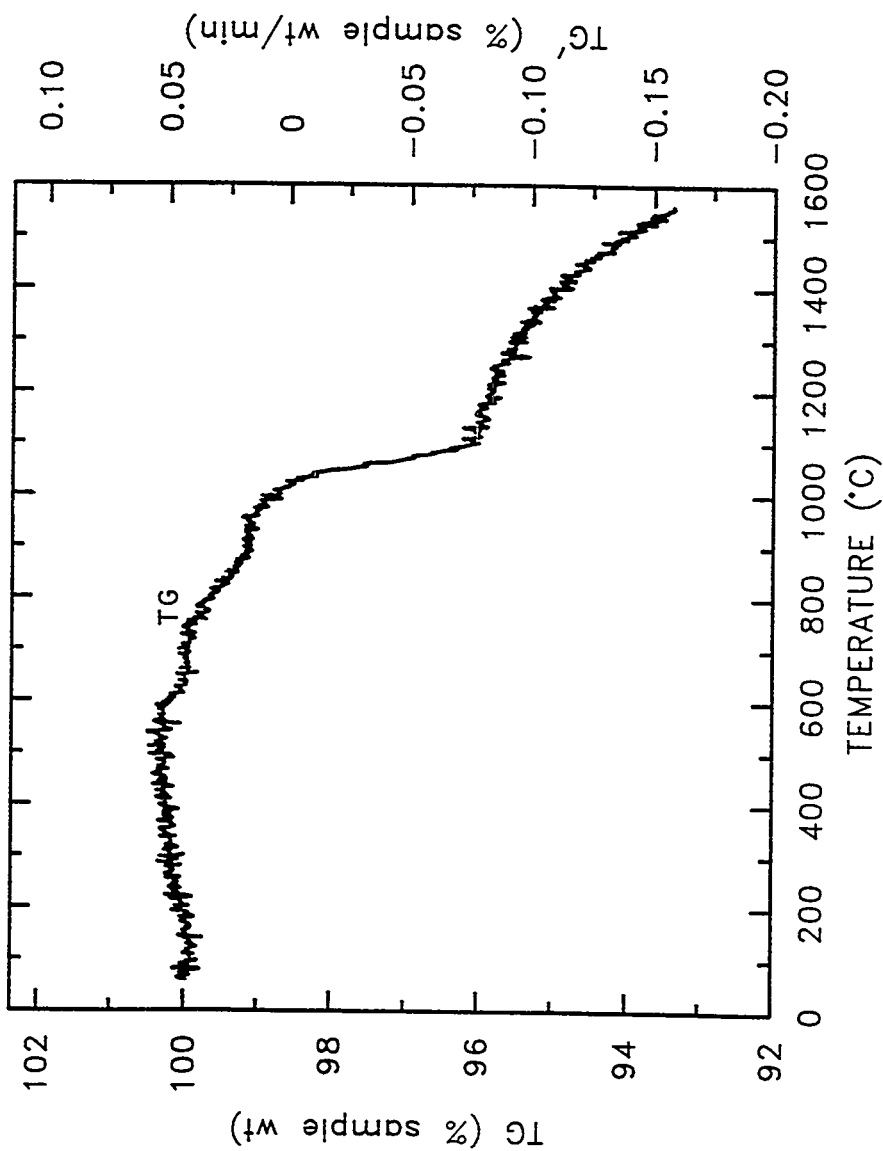
ORNL DWG 94A-793

Operator: JSM  
 Date: 14 Aug 1990  
 Run No.: 1  
 Sample No.: 900801-073  
 Sample Name: ASH

— Netzsch Station No. 1—  
 Reference: Alumina  
 Crucible: Alumina  
 Fill Name: Test: JSM004  
 Lot No.: 3850-47-4

Atmosphere: Air  
 Flow Rate, cc/min: 100  
 Heat Rate, °C/min: 3  
 Sample wt, mg: 50.8  
 Reference wt, mg: 100

TYPE V WASTE AFTER  
 ASHING AT 525°C



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