Recovery and Recycling of Aluminum, Copper, and Precious Metals from Dismantled Weapon Components – 14176

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ABSTRACT

Sandia National Laboratories, New Mexico (SNL/NM) is tasked to support The Department of Energy in the dismantlement and disposal of SNL designed weapon components. These components are sealed in a potting compound, and contain heavy metals, explosive, radioactive, and toxic materials. SNL developed a process to identify and remove the hazardous sub-components utilizing drill presses, band saws, shredders, hand tools, etc. The components were shredded and/or granulated, and separated into aluminum and a precious-and-base-metals fraction using various pieces of size reduction equipment. Plastics were further cleaned for disposal as non-hazardous waste. Circuit boards from hard drives are another revenue stream.

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INTRODUCTION

During the next decade, many nuclear weapon systems in the U. S. stockpile may be retired and dismantled to comply with arms reduction treaties and force restructuring. Published reports indicate that this reduction will lower the U.S. stockpile from a historically level of some 25,000 weapons to approximately 6,000. The weapon systems that have been retired and dismantled include artillery rounds, aircraft-delivered bombs, and tactical and strategic missile warheads. The weapon hardware dates from the 1950s through the 1980s and encompasses a wide range of designs and materials.

The Department of Energy (DOE) is responsible for the design, production, stockpile maintenance, and dismantlement of nuclear weapons. The DOE is also responsible for the final disposal of all dismantled nuclear weapon materials. Although weapon dismantlement is not a new activity for the DOE [1], the potential increased rate of weapon system retirements coupled with stricter disposal regulations has prompted DOE to seek improvements in both its dismantlement and disposal processes. In particular, the DOE has committed to waste minimization and increased material recovery and recycling.

The Disassembly Sanitization Operation (DSO) process was developed and proven successful during the Environmental Restoration Project cleanup of the Classified Waste Landfill site at Sandia National Laboratories/New Mexico (SNL/NM). This site held legacy classified components that needed to be removed and the site needed to be remediated for closure.

A detailed Work Control process and the Sandia National Laboratories Integrated Safety Management System (ISMS) were used during this project.

Since the DSO capability was developed for this cleanup project, the process was recognized as having potential for many applications. The process was identified as being transferable to current-day inventories of classified weapon components that are in long-term storage at Sandia and many other locations throughout the complex. Although older and outdated classified weapons components do not have a future use, they must be securely stored onsite(s) because no disposal path exists for them. By disassembling and sanitizing these classified parts and components, the component metals could be recycled and the remaining materials could be disposed of. This would eliminate the need for long-term storage of this huge inventory of classified weapons components. Prior to the DSO process being used outside of its original application at the landfill, all regulatory requirements were evaluated and adequately satisfied to confirm that the process could effectively be applied to excess, classified weapons components and computer hard drives. The operation focused on processing these classified parts and either removing the classified parts or pieces, or rendering the classified parts or pieces unclassified.

The disassembly process segregates each material type. The sanitization process prevents these materials from continuing to exist as classified part by using a number of methods, including but not limited to, shredding, destruction by a ring mill, cutting with band saws, and/or basic hands-on disassembly of the components. After the parts are sanitized, they are no longer required to be stored as classified matter.

After segregating the metals for recycling, the remaining materials can be managed independently of each other. These additional materials comprise only 20 to 30 % of the components' materials and, as segregated materials, they can be disposed of rather than stored. Some of the materials may be designated as low-level radioactive waste, mixed waste, and hazardous waste.

Sandia National Laboratories is the engineering laboratory responsible for the design of most of the hardware, exclusive of the "physics package," in nuclear weapons. For example, multi-purpose nuclear bomb is broken down into its various components. The "physics package" containing radioactive materials. The remaining components are primarily of SNL design and represent a very diverse group of plastic and metal parts.

Table I lists some of the nuclear weapon components traditionally designed by SNL. These components do not contain special nuclear materials or large amounts of high explosives; however, they may contain hazardous, radioactive, reactive, and toxic materials. Many components are potted with an epoxy material to increase their ruggedness. All components are very compact. These attributes make it difficult to separate them into traditional material streams.

TABLE I Sandia National Laboratories' designed weapon components

CATEGORY	COMPONENT
Complex Electronics	Firesets Neutron Generators Radars Programmers
Electro-Mechanical	Trajectory Sensing Units Pre-Flight Controllers
Passive Electronics	Interconnect Boxes
Radioactive	Neutron Generators Spark Gaps Krytons
Explosive	Timers Detonators Battery Packs Switch packs
Miscellaneous	Cables, Connectors Parachutes Plastic/Foams Cases and Metal Parts O-Rings, Seals, Fasteners Thermal Batteries

DESCRIPTION

Of the components listed, the most difficult to process with current methods are the complex electronics and electro-mechanical devices. A variety of hazardous materials are contained in the assembly including explosives and radioactive materials. These materials are discretely distributed throughout the assembly in smaller sub-components. In addition, the assembly contains a variety of heavy metals, including a significant quantity of precious metals. Estimates indicate that such hardware contains from $5,000 to $15,000 worth of gold, silver, palladium, and platinum per ton of material. When the precious metals are actually separated out from the units you can obtain from a Recycler ~ $400,000 per ton of precious metals.

In general, the ongoing dismantlement of nuclear weapon hardware represents a material stream totaling some 100 -300 tons of material per year for 10 to 15 years, exclusive of the "physics package" and other parts. **This material stream is roughly 30% aluminum, 10% copper, 10% ferrous, 1 % precious metals, 25% other metals and inorganics, and 25% organic (plastics and epoxy).** If separated properly, the majority of material can be recovered through recycling rather than disposed of as hazardous or non-hazardous waste. In addition, the value of the material, in tons of precious metal content, is sufficient to offset the cost of separation processing.

The Sandia National Laboratories proposed and demonstrated an "end-to-end" process, which included several major steps. These are: (1) hazard-separation, (2) demilitarization, sanitization,

(3) material separation, and (4) recycling and treatment. During hazard-separation, weapon components (such as the arming, fuzing, and firing assembly) would have the smaller sub-components containing hazardous materials cut-outs. These smaller sub-components would then be separated and treated as hazardous waste, LLW, or mixed waste depending on the makeup of the item. The remaining assembly (the bulk of the material) would then be processed for metals recycling and precious metal recovery. During demilitarization and sanitization, all non-hazardous components would be crushed to remove any classification restrictions and to prevent further military use. This process would also act to liberate materials sufficiently to allow material separation as a precursor to recycling. Crushed material would then be processed for material separation.

Hazard separation processing serves an important function, the separation of weapon components into readily disposable waste streams and non-hazardous, recyclable materials. The types of "hazards" requiring removal include: radioactive materials, hazardous materials, explosives, reactive metals, oil-filled components, flammable solids, and inhalation hazards.

These "hazards" are typically in the form of small sub-components located internally to larger electronic or electro-mechanical assemblies. The Resources Conservation and Recovery Act (RCRA) regulate disposal of many of the hazardous materials listed.

The Hazard Separation System (HSS) is based upon current dismantlement and disposition processes. The primary processes are the Jacobson Particilizer (Figure 1), band saws (Figure 2), drill presses, (Figure 3), log splitter (Figure 4) and Thor Ring Mill (Figure 5). Process knowledge and databases are utilized to determine the location of hazardous items within the components.

Figure 3. Wilton Drill Press

Figure 4. Iron and Oak Log Splitter

Figure 5. Thor Ring Mill

Under the disassembly process, demilitarization and sanitization processing occurs after hazard separation and prior to material separation and recycling or treatment. This type of processing is necessary in order to remove the material from the DOE's inventory and release it to industry for recycling and precious metal recovery. The DOE requires that all dismantled weapon components be altered to the extent that they may not be used for their intended purpose. This is called demilitarization.

Furthermore, many components (including most complex electronic and electro-mechanical devices) are classified. The DOE requires that all classified traits be totally removed prior to release. This is called sanitization. DSO has proposed size-reduction techniques as an efficient means for accomplishing both demilitarization and sanitization. In addition, such a process could be used to prepare the material for subsequent material separation processing and/or thermal treatment.

Approximately 20 tons of material was size reduced during fiscal year 2010. The processes were compared for efficiency, size reduction capability, and material liberation capability.

Log Splitting at SNL involved a weapon component and log splitting the item to remove capacitors, transformers, and/or circuit boards. Although the method adequately provided demilitarization and sanitization, little size-reduction occurred, but it had material liberation capability

Another size-reduction process demonstrated was shredding. Depending on the material SNL used various sized shredders with different screen sizes. The industrial shredders provided large throughput and continuous operation. The smaller shredders (25Hp) did adequately sanitize small, classified sub-components and some especially rugged components proved easy to downsize at all. By varying screen size, the shredder discharge output material size was adequately controlled

Other experiments were conducted to remove hazards from the weapon components. Most weapon components could be processed using the drill press or band saw; the majority of components were processed very effectively. Components were broken up and materials well liberated.

The waste fraction of the separation products consisted mostly of plastics, potting material, graphite, ceramics, and less than 3% metals. Metallic inclusions were mostly aluminum flakes, which were carried into the light fraction, and thin copper wires entrained with the plastics. This fraction accounted for about 23-wt% of the granulated material.

Preliminary tests using Environmental Protection Agency (EPA) Toxic Characteristics Leaching Procedure (TCLP) indicated that the coarse table tailings met the regulatory limits for all regulated metals (i.e. chromium, mercury, silver, and zinc) except lead and cadmium. Because disposal of this material to a hazardous-waste depository would be costly (due to its low bulk density and high volume), an alternative method of recycling this material was investigated and used.   "Regulatory limits: lead (5.0) and cadmium (1.0).

Circuit boards that have been removed from the various weapon components and are shredded. Circuit boards were also obtained from the destruction of classified hard drives. A typical separation of a hard drives utilizing hand tools and a shredder is shown in Figures 6 and 7. The circuit boards are shredded separately from the platters. Everything from a hard drive is recycled and usually will provide ~ $20,000 per ton of circuit boards.

Figure 6

Figure 7

Smelting is the most widely used method for recovering precious metals (PM) from printed circuit boards and other electronic scrap. There are a number of well-established secondary metal smelters in the country. Recovery methods typically include the removal of organic material by thermal decomposition, dissolution of PM-bearing scrap in molten copper, oxidation of impurities to slag, and casting of ingots.

Smelting tests were conducted at the Gannon & Scott Facility in Phoenix Arizona. Smelting/assay tests were conducted with disassembled and shredded components and circuit boards. Slag and melt were then sampled and assayed separately. Smelting-assay tests on a sample of granulated material used for separation tests, and on a composite PM concentrate of separation products, were also conducted.

CONCLUSIONS

Results of the separation, described above indicated a number of benefits from reducing the amount of material to be treated at a smelter through removal of coarse aluminum and plastics. These benefits include recovery and recycling of aluminum, disposal of bulk of the plastics as non-hazardous waste, and reducing the transportation costs and smelting charges.

The installed cost of the crushing and separation system can be expected to approach $500,000, excluding the building cost and Local Exhaust Ventilation (LEV) System. Against the capital and operating costs, however, the increase in smelter returns should be considered. A sampling and analysis of the weapons components to be recycled has not been completed, a extrapolated estimate of the metal values in these components for the projected volume of 100 tons per year are tabulated in Table II.

Table II Estimated value of processed weapon components

Plugs, Connectors, and Gold Plating
Weight – 2000 metric pounds (0.91 ton)

Material	Amount	Value	Total
Gold	19.86 metric lbs. (350.21 Oz)	$22932.00/metric lb. (17.64 Oz)	455,273.00
Silver	0.37 metric lbs. (6.58 Oz)	$412.42/metric lb. (17.64 Oz)	$153.84
Copper	24.43 metric lbs. (430.94 Oz)	$56.98/metric lb. (17.64 Oz)	$1,391.94
Palladium	Trace	$10549.00/metric lb. (17.64 Oz)	$0.00
	Total		$456,818.78
	Net Pay Out		**$410,134.66**

Circuit Boards
Weight – 2,000 pounds (0.91 ton)

Material	Amount	Value	Total
Gold	1.04 metric lbs. (18.26 Oz)	$22932.00/metric lb. (17.64 Oz)	$23,738.00
Silver	3.79 metric lbs. (66.85 Oz)	$412.42/metric lb. (17.64 Oz)	$1,562.95
Palladium	0.23 metric lbs. (4.01 Oz)	$10549.00/metric lb. (17.64 Oz)	$2,397.98
	Total		$27,698.93
	Net Pay Out		**$20,774.20**

The recycle value of the recovered aluminum (<$1 K) is minimal as compared to the value of precious metals. However, smelting costs are reduced by 50% when coarse aluminum and plastics are separated from the material to be treated at the smelter. Furthermore, aluminum is a troublesome diluent for the smelters; once it is removed from the smelter feed, a more favorable treatment rate can be negotiated [6]. Savings in the treatment charges would result in higher revenues than can be realized by weight reduction alone. It is estimated that granulating and separating the shredded material can thus save $200 K per year. This amount would most likely pay for the separation equipment (excluding the building and LEV system) in the first year, and annual operating expenses for subsequent years. In addition, recycling aluminum would save energy and demonstrate a commitment to recycling consistent with DOE objectives.

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