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Pollution Prevention Opportunity Assessment for Propellants, Explosives, and Pyrotechnics

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**POLLUTION PREVENTION OPPORTUNITY ASSESSMENT
FOR
PROPELLANTS, EXPLOSIVES, AND PYROTECHNICS**

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ABSTRACT

This pollution prevention opportunity assessment was conducted to document the activities at SNL/California that have involved propellants, explosives, and pyrotechnics; and to outline options for minimizing energetic materials and waste at SNL/California.

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CONTENTS

	Page
Executive Summary	7
Introduction	9
Pollution Prevention Opportunity Assessment	10
Facility.....	10
Products	10
Background	10
Material/Waste Stream Profiles	15
Waste Generation.....	15
Energetic Material Minimization/Disposal Options	15
References	20
Bibliography.....	21

ILLUSTRATIONS AND TABLES

No.	Page
Fig. 1 PEPER's Cradle-to-Grave Process	12
Fig. 2 Process Steps for Acquisition of Energetic Materials at SNL/California.....	13
Fig. 3 Use and Storage Process.....	14
Fig. 4 Disposition Process Using Resource, Recovery, and Disposition Account (RRDA)	14
Table 1 Disposal Options for Energetic Materials.....	19

EXECUTIVE SUMMARY

The purpose of this PPOA is twofold: to document the activities at SNL/California that have involved propellants, explosives, and pyrotechnics; and to outline options for disposing of energetic waste.

In 1991, a DOE "Tiger Team" audited the Sandia Explosives Program and cited Sandia for not having an Explosives Storage Review Program. In 1992, in response to the Tiger Team findings, Sandia formed the Propellants, Explosives, and Pyrotechnics Evaluation and Reapplication Task Force (PEPER) to develop the tools to implement cradle-to-grave management of energetic materials at Sandia. PEPER met the following objectives:

1. create an accurate inventory of all energetic materials owned by Sandia—PEPER developed the Explosive Information and Inventory System (EIS) and the Resource, Recovery, and Disposition Account (RRDA), which are now used to manage Sandia's inventory of energetic materials;
2. evaluate the stability of the inventory, and thereby identify and destroy all imminent hazards—the Demilitarization and Disposal Strategies for Small Energetic Weapon Components (DADSEWC). DADSEWC, a two-year project, focused on forms of disposal other than open burns or open detentions, and confined burns of energetic materials;
3. draw down the inventory to be consistent with post-Cold War business needs—PEPER provided an opportunity for owners of explosives to reduce their excess inventories through disposal, and the DADSEWC researched recycling technologies for explosives recovered in the dismantlement of weapons components;
4. create a cradle-to-grave ownership process.

Sandia's philosophy on energetic materials and energetic wastes is conservative. SNL's primary goal is reapplication or recycling of surplus energetic materials. If the materials must be disposed of, SNL uses only Resource Conservation and Recovery Act (RCRA)-approved waste disposal facilities. This conservative approach, as well as the fact that some of the materials are Classified, limits Sandia's disposal options.

However, several waste minimization options are available for reducing the energetic material inventory at SNL/California:

- Reapplication—Sandia already has successfully reapplied several types of energetic materials: rocket motors donated to other government organizations, bulk explosives, and gun propellants and rocket motor propellants converted to a variety of new products.
- SNL/New Mexico has a permit for transferring energetic materials to Kirtland Air Force Base for open burn or open detonation; it has expanded its permit to accept hazardous energetic wastes from SNL/California.
- ICI Corporation rotary kilns (contained thermal treatment systems), which were evaluated by Sandia in 1994. The ICI Joplin, Missouri, facility is a fully functioning RCRA-permitted commercial hazardous waste treatment, storage

and disposal site. This facility can process nonClassified DOE materials and holds a DoD clearance. The DOE could give ICI clearance to receive Classified materials on an as-needed basis.

- PEPER successfully addressed the issues cited by the Tiger Team, and the DADSEWC program was a major contributor to solving the energetic material waste disposal issues. However, both programs were terminated when they were about 90% complete. Further funding is needed to continue research into disposal options (other than reapplication).

Future options for the SNL/California inventory of small energetic components include the following disposal methods; these options must still be approved and permitted by the EPA in accordance with RCRA:

- Plasma arc technology, under research by Plasma Energy Applied Technology (PEAT) and Retech, can be applied to the thermal decomposition and vitrification of energetic materials. These processes use a plasma torch and hearth to thermally destroy energetic feed materials. The end result is a stable and non-leaching glassy slag. Facilities are not yet available to treat SNL/California's small energetic components.
- Cryocycling or cryofracture, which is a process used to reclaim explosives or propellant for recycling and reuse. The Sandia-developed cryocycling process is an effective, environmentally benign, and safe method for reducing the size of many solid propellants. Cryofracture and washout processes for the large motors in Sandia's inventory have been evaluated, and both have been successful for recycling propellants. The projects need further funding to be implemented as processes.

POLLUTION PREVENTION OPPORTUNITY ASSESSMENT FOR PROPELLANTS, EXPLOSIVES, AND PYROTECHNICS

Introduction

Department of Energy (DOE) orders 5400.1 and 5400.3 mandate the development of a waste minimization program.^{1,2} The program's goals are to:

- reduce volumes of hazardous wastes and toxicity,
- implement a system of tracking and reporting improvements, and
- devise a method for performing tasks.

To satisfy the requirements of this program, Sandia conducts pollution prevention opportunity assessments (PPOAs) to identify waste-generating processes. The information collected from a PPOA then is used to identify waste minimization opportunities.

SNL/California conducts PPOAs in accordance with the *Pollution Prevention Opportunity Assessment Plan for SNL/California*.³

SNL/California has conducted PPOAs on the largest waste-producing processes containing one or more of the priority waste streams. The remaining waste streams to be assessed are generated by small processes. Conducting an assessment on each one of these processes is not cost or time effective. Therefore, Sandia developed a new methodology to allow for a site-wide approach to single waste streams, such as energetic materials, ozone-depleting compounds, carcinogens, EPA 33/50 target chemicals, and other site-specific materials.

This new methodology changes the traditional approach from assessing a waste generator (and all waste streams produced by that waste generator) to assessing single waste streams generated by a number of waste producers site-wide. The DOE Division of Waste Management (EM-334) funded the initial development of this methodology and has provided funding for Sandia to conduct site-wide assessments on single priority materials/waste streams. SNL/California environment, safety, and health (ES&H) personnel developed and management approved a prioritized list of these priority waste streams, based on DOE requirements, guidance, and executive orders. The new methodology and the prioritized list were incorporated in the latest revision of the *Pollution Prevention Opportunity Assessment Plan for SNL/California*.³ ES&H personnel can add waste streams to the priority list, as required, with management approval.

This is the first PPOA to be conducted using the new methodology. The waste stream assessed is propellants, explosives, and pyrotechnics material. The purposes of this PPOA are: 1) to describe the programs, systems, and methods of management used by Sandia to control the energetic materials waste stream, and 2) to list options available for minimization of these materials and the resulting waste stream. This PPOA was done specifically for SNL/California, but the material and waste minimization options described can be applied to other sites with similar energetic material inventories.

Pollution Prevention Opportunity Assessment

Facility

SNL/California has approximately 100 lb. explosive materials on site (out of a capacity to store 700 lb.), which are stored in magazines on the southern boundary of the site near Building 982.

Products

The Explosives Safety Program manages the site-wide storage of energetic materials, maintains the Explosive Information and Inventory System (EIS), and offers extensive training on all aspects of explosives. The Explosives Safety Program also is responsible for consulting with owners of explosives on their safe use and for ensuring SNL/California's compliance with all State and Federal regulations for explosives storage and handling.

Background

In 1991, a DOE "Tiger Team" audited the SNL/California Explosives Program and cited Sandia for not being in compliance with the DOE Explosives Safety Manual requirements for having an explosives storage review program. At that time, SNL/California did not have a site-wide inventory record of explosives, and no storage review was in place. Sandia corporately owns approximately 1,800,000 lb. energetic material, which is located at various sites throughout the country.

In 1992, in response to the Tiger Team findings, Sandia formed the Propellants, Explosives, and Pyrotechnics Evaluation and Reapplication Task Force (PEPER) to "develop the tools to implement life-cycle management of energetic materials at Sandia."⁴ PEPER met the following objectives:

1. create an accurate inventory of all energetic materials owned by Sandia;
2. evaluate the stability of the inventory, and thereby identify and destroy all imminent hazards;
3. draw down the inventory to be consistent with post-Cold War business needs;
4. create a cradle-to-grave ownership process.

Inventory of Energetic Materials

PEPER developed tools to help the Explosives Program Manager and the Sandia Explosives Safety Committee (SESC) manage SNL energetic material inventories. One of these tools is the EIS, an interactive database, used to identify, log, and track all the energetic materials in the Sandia corporate inventory. PEPER also developed the Resource, Recovery and Disposition Account (RRDA) database, which maintains the availability information for all transferable material, a list of the final disposition of all energetic materials, and a summary of dispositions.⁴

Sandia has a very small amount of explosive material stored as hazardous waste and is investigating avenues for disposing of it.

SNL stores all propellants, explosives, and pyrotechnics as hazardous material in accordance with the Resource Conservation and Recovery Act (RCRA). This is considered conservative because the EPA has not yet required owners of these materials to store them in accordance with RCRA. Other government agencies, such as the Department of Defense, and some industries, such as the rocket motor industry, do not follow such a strict storage policy.⁴

Identify and Destroy Imminent Hazards/Draw Down Inventory

The DOE Office of Technology Development sponsored the Waste Component Recycle, Treatment, and Disposal Integrated Demonstration (WeDID) program to research recycling technologies used in the dismantlement of weapons components. However, this program did not include recovery of explosives, but it did lay the ground work for Demilitarization and Disposal Strategies for Small Energetic Weapon Components (DADSEWC). DADSEWC was a two-year project focused on forms of disposal other than open burns or open detentions, and confined burns of energetic materials. DADSEWC concentrated on small components, rather than bulk energetic materials or rocket motors. Among the many things this program considered were resource recovery and recycling.^{5,6}

PEPER provided an opportunity for owners of explosives to reduce their excess inventories through disposal, which was paid for out of a designated Sandia case number (rather than being charged to the owners' case numbers). The owners evaluated their programmatic needs and identified excess material for disposal.

PEPER and DADSEWC both accomplished significant milestones toward the management and minimization of Sandia's energetic materials inventory. For example, through the efforts of PEPER, Sandia saved \$1.2 million in 1994 and 1995 by removing excess energetic materials inventory and using it for reapplication.⁴ However, both PEPER and DADSEWC were terminated when they were about 90% complete. PEPER's inventory reduction has not been completed, and DADSEWC was still identifying sources for reapplication of small materials and investigating methods of disposal. More funding will be needed to address the final issues to implement the cradle-to-grave philosophy.^{5,6} The EIS database is operating, but due to the lack of funds, is being maintained only in an intermediate mode and has not been advanced to the higher operating level originally planned.

Cradle-to-Grave Process

PEPER's cradle-to-grave process for energetic material management can be divided into four basic steps, or processes (see Fig. 1):⁴

- A. Acquisition
- B. Use
- C. Storage
- D. Disposition

Figure 1. PEPER'S Cradle-to-Grave Process⁵

A. Acquisition

Acquisition justification requires the owner to provide for the life cycle of the material to ensure compliant use, storage, and disposal. The two basic steps required for the acquisition of energetic materials are (see Fig. 2):⁴

1. Controlled Pre-acquisition and Definition of Life Cycle
2. Acquisition and Receipt

B. Use/C. Storage

The justification for continued storage requires the owner to conduct periodic storage reviews, considering the programmatic needs and the storage life of the material (see Fig. 3).⁴

D. Disposition

Disposal of material excess to programmatic needs must be processed for reapplication or declared waste. Material identified as waste must be processed expeditiously and in compliance with applicable safety and environmental regulations (see Fig. 4).⁴

Figure 2. Process Steps for Acquisition of Energetic Materials at SNL/California⁶

Figure 3. Use and Storage Process⁶

Figure 4. Disposition Process Using the Resource, Recovery, and Disposition Account (RRDA)⁸

Material/Waste Stream Profiles

Approximately 20 to 30% of SNL/California's total explosive inventory is Classified.⁹ Commercial facilities for disposal of explosives are available, but the permitting limitations for the disposal of Classified explosives are extensive. Very few sites are permitted to accept Classified explosive material.

The EPA published the Military Munitions Rule: Hazardous Waste Identification and Management; Explosive Emergencies; Redefinition of On-Site; Proposed Rule.¹⁰ This proposed rule outlines the conservative approach to the storage and maintenance of explosive materials that already exist at SNL. When the status of an item changes from material to waste, the methods of treatment are more severely limited. A waste cannot be used for reapplication; disposal becomes the main focus. Treatment methods for waste and material are discussed in "Energetic Material Minimization/Disposal Options."

Waste Generation

At SNL, propellants, explosives, and pyrotechnics are handled and stored as hazardous material. The primary goal for these materials is reapplication or recycling, consistent with RCRA guidelines. All excess explosives are stored as inventory. SNL/California now has a very small amount of Classified explosive waste in storage as hazardous waste.

Energetic Material Minimization/Disposal Options

Reapplication

Reapplication is the use of explosive material for a purpose other than what it was originally intended. SNL maintains excess material as assets for resale or use in R&D projects (tracked in RRDA). PEPER and DADSEWC accomplished the following reapplications:⁴

- rocket motors were donated to other government organizations for use on sled tracks;
- bulk explosives were provided for creating explosives environment ;
- gun propellants and rocket motor propellants were converted to a variety of new products, including booster charges for mining and commercial blasting, specialty explosives, boiler fuels, and animal feed supplements.

The DADSEWC project team held monthly meetings to discuss, among other topics, the status of reapplication projects and possible future participants. Since the project's termination, SNL/California has been seeking candidates to take over this function. Reapplication is a high priority in the Explosives Safety Program. Not only is it a good waste minimization option, but it also is a good cost savings measure.

Open Burn/Open Detonation

Open burn (OB) and open detonation (OD) are conducted in large open areas. These processes involve detonating or burning the energetic waste without emissions controls. They have been the traditional and least expensive methods used to dispose of energetic materials. However, OB and OD are becoming less environmentally acceptable because of

the air emissions and solid waste generated. Stricter environmental regulations have caused the practices to be banned or significantly restricted in some cases. The impact of Title 40 CFR Part 260 on OB and OD is not known; however, speculation is that it will restrict the practices significantly.¹⁰

SNL/New Mexico has always sent explosive materials to Kirtland Air Force Base in Albuquerque for OB or OD. SNL/New Mexico has addressed the permitting issues that have restricted SNL/California from these transactions, and SNL/California can now transfer explosive material waste to SNL/New Mexico for OB or OD at Kirtland Air Force Base.^{11,12}

SNL, Lawrence Livermore National Laboratory (LLNL), and Los Alamos National Laboratory (LANL) have joined forces with the DoD to conduct tests on OB and OD, using surplus inventory. Rocket motors will be burned or detonated in test tunnels (built in the mid-1980s) at the Nevada Test Site to measure both gas emissions and solids residues from OB and OD. The goal of these tests is to better understand emissions and residue fallout related to field conditions. This testing tentatively starts in August 1996, and is scheduled to last 18 months.¹³

Contained Thermal Treatment Systems

Contained thermal treatment systems are an alternative to OB and OD. The basic design is an enclosed thermal treatment unit, and the technology is the destruction of waste through incineration. Several types of incinerators fall into this category, such as the rotary kiln incinerator. ICI Corporation has rotary kilns in Joplin, Missouri, which the DADSEWC project team evaluated in 1994. ICI's facility is a fully functioning RCRA-permitted commercial hazardous waste treatment, storage and disposal site. It has a DoD clearance, but it is not certified for DOE Classified waste. The DOE could give ICI clearance to receive Classified materials on an as-needed basis.¹⁴

Cryocycle or Cryofracture

Cryocycling or cryofracture is a process used to reclaim explosives or propellant for recycling and reuse. The Sandia-developed cryocycling process uses liquid nitrogen (-320°F) to fracture propellant grains into small pieces. These pieces then pass through a screener process to reduce their size to <0.75 in. The pieces are packaged into 35-lb. bags for reuse in commercial applications, such as mining explosives or sporting powders. The process requires several steps to accomplish the size reduction. It is summarized in the *Final Report on Processing Sandia Rocket Motors and Reclaiming Propellant for Recycling and Reuse*.¹⁵

This Sandia-developed process appears to be an effective, environmentally benign, and safe method for reducing the size of many solid propellants.¹⁵ A total of 5,236 lb. propellants have been reclaimed using this process. The following are examples of the benefits of this process:

- Cryocycling uses nitrogen, one of the least reactive, cheapest, and safe elements known; there are no current or anticipated emission regulations for nitrogen.

- Propellant sensitivities do not increase as a result of cryocycling.
- Cryocycling does not alter propellant composition; all the inherent energy of the propellant may be reused in a number of high-value products.
- Cryocycling requires no moving parts to be in contact with the propellant, which increases safety.
- Cryocycling produces no waste stream.

Oak Ridge National Laboratory also is conducting cryocycling research. In the future, Oak Ridge may be able to accept explosive material waste on a research basis, using a Treatment Permit for waste.¹⁶

Plasma Arc Technology

Two companies, Plasma Energy Applied Technology (PEAT) and Retech, a division of Lockheed Martin Products, are researching the application of plasma arc technology to the thermal decomposition and vitrification of energetic materials. These processes use a plasma torch and hearth to thermally destroy energetic feed materials. The end result is a stable and non-leaching glassy slag.

A plasma torch can generate temperatures in the range of 5000 to 6000°C. Depending on the gas or gasses used, the hearth atmosphere can be controlled from reducing to oxidizing. The atmosphere used depends on the type of materials to be destroyed. The high temperature is generated by passing the gas through a high-energy arc between electrodes. The gas becomes charged through electron stripping and ionization. High-level thermal energy is created as the electrons recombine with the stripped electrons.^{17,18,19,20}

Two configurations of plasma processes are under development:

- One uses a nontransferred arc torch with two electrodes, and the dispersed heat pyrolyzes the feed material.
- The other uses a transferred arc torch with one electrode, and the ground is the feed material. Pyrolysis in this unit is achieved by intense direct heat.

The PEAT Thermal Destruction and Recovery (TDR) System uses the nontransferred arc torch, operating in a reducing atmosphere, to pyrolyze the energetic material fed into it. This system can dispose of energetic materials in bulk condition. The PEAT TDR System has been tested successfully on a number of DOE and DoD explosive components, such as:²⁰

- Small energetic items (bolts, gas generators, detonators, actuators).
- Gun powder and small arms ammunition (.30 and .50 caliber).
- Rubberized and whole weapon component material.
- Pyrotechnic materials (flares and smokes).

The results of the reaction in the processing vessel are:²⁰

- energetic materials are rendered nonhazardous;
- hazardous materials are immobilized in a non-leaching glassy slag;
- metals from the slag can be recovered;

- air and water emissions meet EPA and industrial sewer regulatory requirements.

This system has been extensively evaluated by Sandia and appears to be a feasible method for disposal of small components, but there is no facility available for this purpose. Pantex may install a unit in the future, but funding is not available.

Retech, in Ukiah, California, has developed a process around the transferred arc torch, Plasma Arc Centrifugal Treatment (PACT). This process uses a centrifugal hearth to distribute the heat uniformly through the slag and to create a homogeneous mixture.^{17,18,19}

Retech is installing several plasma arc units in the U.S., Europe, and Asia. These units are used for a variety of applications. For example, in Butte, Montana, MSE Technological Applications, Inc., is overseeing the Western Environmental Technology Office, a DOE facility, which is conducting treatability studies using a Retech PACT-6 unit on explosive materials on a Treatment Permit basis.²¹ Another example is the Retech PACT-2 system, a portable unit, which can be mounted into two 8' x 8' x 10' shipping containers.¹⁷ A transportable plasma torch unit is beneficial to sites with large inventories of small components. The unit can be brought to a site, the components disposed of, and the unit moved on to the next site, thereby saving the cost of packaging and shipping the components to a disposal site. The major problem with a transportable unit is obtaining permits to use the unit in different regions of the country. Now, MSE is not a permitted RCRA facility and cannot handle Classified waste.

Retech recently bid on the Idaho National Engineering Laboratory (INEL) cleanup of Pit 9. The remediation of Pit 9 involves soil that is contaminated with plutonium. Future waste cleanup may be scheduled, depending on which company wins the contract for the next phase of this project. INEL should award the contract by October 1996.²²

Washout

On a prime contract with Sandia, Day and Zimmerman Hawthorne Corporation completed a pilot project to wash out 220 excess HAWK rocket motors in September 1995, using a high-pressure water lance. Precision timing and movement of the lance are used to achieve the proper configuration of propellant pieces. The propellant pieces then are collected and dewatered (by pressing). The reclaimed propellant from this process can be reused in the formulation of water gel slurry for the commercial mining industry.²³

Table 1 summarizes the location and contact names of current and future waste minimization options.

Table 1. Disposal Options for Energetic Material Waste

Current Options:	Location	Contact Information and Comments
ICI	Joplin, MO	Curtis DeMille, (610) 666-8698; Incineration
MSE Technological Applications, Inc.	Butte, MT	Craig Filius, (406) 494-7277; Plasma Arc Treatability Studies conducted on a Treatment Permit basis.
Chemical Waste Management	Sauget, IL	Jim Joseph, (618) 271-2804, ext. 23; Incineration
Kirtland AFB	Albuquerque, NM	Dave Castillo, (505) 848-0482; Waste would go to SNL/New Mexico, then on to Kirtland Air Force Base for OB/OD
Oak Ridge National Lab	Oak Ridge, TN	Doris Fraiser, (423) 574-5776; Research in various disposal methods on a Treatment Permit basis.
Future Options:		
Idaho National Engineering Lab	Idaho Falls, ID	Mike Barret, (208) 526-9621; The second phase has not been awarded. Award date is 10/96. This would involve plasma arc technology.
Pantex Weapons Facility	Amarillo, TX	Dr. Martin Springer, (205) 859-3006; PEAT, Inc.

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