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**STRATEGIES FOR THE DISPOSITION OF HIGH EXPLOSIVES
RESULTING FROM DISMANTLEMENT OF NUCLEAR WEAPONS***

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ABSTRACT

Many thousands of pounds of high quality main-charge explosives will result as surplus from the dismantlement of returns from the U.S. nuclear weapons stockpile. The method most often employed for dealing with this surplus explosive is destruction by open burning. However, open burning as a means of treating excess explosives is losing favor because of environmental concerns associated with such an uncontrolled thermal destruction process. Thus, alternative processes for treatment of excess explosives from weapon dismantlement is discussed. These alternatives include: reformulation, crystalline component recovery, chemical conversion of the crystalline component to higher value products which may have civilian or military applications and, when necessary, treatment as waste in an environmentally benign fashion.

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INTRODUCTION

Over the next decade the United States will dismantle thousands of nuclear weapons. Most of these weapons contain high quality nitramine-based explosives as main-charges. Typically, these materials are destroyed by open burning and/or open detonation. The method of open burning as a means of destruction of explosives, or energetic materials in general, is rapidly becoming unacceptable in the United States because of environmental considerations. There is an inability to accurately determine and control the type and quantity of emissions which result from this uncontrolled thermal destruction process. These nitramine-based plastic-bonded explosives (PBXs) are primarily comprised of 1,3,5,7-tetranitro-1,3,5,7-tetrazacyclooctane (HMX). The synthesis of HMX is expensive, neat HMX costs \$16-24/kg (depending on material specifications), in addition to the PBX processing costs. In this report we discuss some strategies for the disposition of these explosives. Figure 1 is a flow diagram which shows the flow of high explosives once disassembled from the weapon. The solid line flow of explosive in the diagram goes directly to open burn/open detonation destruction, which is currently practiced today. The dashed-line explosives flows are paths to alternatives to destruction. This entails size reduction of the classified shapes of the main-charge explosives followed by shipment to industry for processing. The processing may include reformulation into the plastic-bonded form for reuse as in the original application, or, for extraction of the crystalline explosive component for formulation into other explosive products. Another alternative is the use of the extracted explosive as chemical feedstock for chemical conversion to other higher value products which may have civilian or military application (the use of TNT as feedstock is discussed elsewhere in these proceedings). Finally, next-generation disposal technologies for energetic materials which are environmentally benign, permissible, and politically acceptable must be developed. Thus, the approach is to treat excess energetic materials as an asset rather than a waste with industry acknowledged as a partner in the management of these materials in terms of processing technology, brokerage of the material, and, as a customer. Although the emphasis is on the disposition of Department of Energy (DOE) explosives, the approaches discussed here may have application to the disposition of excess explosives and other energetic materials associated with the demilitarization of conventional munitions.

DISCUSSION

Size Reduction

The main-charge explosives removed from weapons are in the consolidated form (made from thermoplastic-based molding powders), are classified because of shape, and must be declassified and reduced to a smaller size. The method currently used for size reduction is standard explosion-proof lathe machining using steel-tool bits. This process results in very small particles (shavings) of explosive, in the range of 100 to 1000 μm , which can be used efficiently for reformulation, chemical extraction, or destruction processes because of the small size. Machining is attractive because the equipment is easily available within the DOE and the process is cost-effective for size reduction for typical main-charge shapes.

However, there are unique main-charge shapes which make standard machining unsuitable (*i.e.* labor intensive or time consuming and cumbersome) and thus other methods have to be considered. One method showing promise for main-charge part reduction is fluid-jet (*e.g.* water). Industry uses this process already for cutting and removing propellants from rocket motors and main-charge explosives from conventional munitions. One disadvantage to this process is that the particle size is generally greater than optimum and may require further reduction to obtain smaller sizes for continued processing. Secondary size reduction can use inexpensive blade-choppers, Cowles dissolvers, or crushers.

Industry Participation

Department of Energy explosives are manufactured by the private sector under a Department of Defense contract. This same contractor may be considered as the primary industrial contact for receipt of DOE dismantlement high explosives. Other commercial explosives manufacturers are interested in receiving the recovered nitramine explosive for use in a variety of applications such as boosters and energetic additives with emulsion blast charges. There are several disadvantages cited by private industry with regard to acceptance of these energetic materials. First, the legal liability issue of ownership should an accident or unexpected violent reaction occur in processing "previously owned" explosive. Second, concern regarding a guaranteed consistent source supply for receipt by the industrial sector. Third, even if maximum shipments were made reliably, the quantities envisaged (several thousand pounds per year) do not make a significant impact on the commercial sector because of the low volume available (their use of energetics is in the billions of pounds per year).

There are advantages for industrial participation; these are that, for minimal cost, high quality explosives are available to interested parties and, in the interest of waste minimization, valuable energetic molecules can be recycled for reuse or for other applications rather than being destroyed.

Reformulation

The first priority in the management of excess PBX is cost-effective processing (other than burning). Reformulation requires minimal processing *i.e.* PBX which has been decreased to small particles and analyzed for composition is then reformulated by the original processing method, adjusting for explosive or polymer content as determined by composition analysis. The PBX is now in the molding powder form and available for applications where high performance HMX-based explosives (wt. %: 95 HMX/5 polymer) are desired. The disadvantage to this process is that DOE no longer has a requirement for these relatively sensitive, high performance type of PBXs and thus would not be a customer for reformulated HMX PBXs. Industry and DoD also have little need for such formulations as the propellant industry uses neat HMX in their applications and DoD already has their own qualified formulations based on very specific applications. The DOE, however, currently uses reformulated TATB-based PBXs in weapon applications.

Explosive Recovery

A very attractive option for disposition is the extraction or separation of explosive components from the formulations into the neat form. By this approach the recovered explosive can be used in any application that would normally use virgin material. In the case of HMX-based PBXs, the HMX is selectively extracted by dissolution, precipitated, filtered and recovered. Although the majority explosive component expected to be recovered from DOE formulations is HMX, other explosives that can also be recovered are RDX, TNT, and TATB.

There are some issues which need to be addressed before there is complete acceptance of the reuse of recovered crystalline explosives. First, the issue which constantly arises is associated with the character of the explosive molecule once it has been through the recovery process. For example, the solvent most frequently used for the dissolution of HMX to extract it from PBX is dimethylsulfoxide (DMSO). A concern is that residual solvent in the explosive crystal may affect sensitivity and/or performance. In the United

States, most of the nitramine explosive powder product specification is strongly driven by the chemistry and protocol of the production process. That is, when there is a change in the detailed chemistry and/or protocol of the production process, although the product meets the specification, the performance of the formulation (whether it is explosive or propellant) must nevertheless be tested against the performance of formulations made from the previous process. The qualification of munition systems or rocket motors are heavily dependent on the crystalline component and are very expensive tests. Thus the impetus to use recovered crystalline explosives is low and leaves their reuse to less high performance or critical applications.

Although RDX and TNT are strong candidates for reuse, the application performance window is less narrow than for formulations requiring HMX, there is a reluctance to use "previously owned" and reprocessed explosive components without extensive and expensive testing. TATB as a recovered crystalline component is also valuable for reuse but only in DOE applications as the DoD considers this insensitive molecule too expensive for large-mass applications. The TATB molecule is indeed expensive (\$25/pound) and very stable and insoluble. This high stability makes it amenable to many recovery process cycles without degradation of its properties. The only drawback is the decrease in particle size which occurs during the consolidation and machining steps in main-charge manufacture. Increasing the particle size to bring it to acceptable sizes is being addressed by F. Foltz at our laboratory. Foltz is performing TATB recrystallization and crystal growth studies where crystals in the range of 100 to 2000 μm particle size have been successfully obtained.

Chemical Conversion

There are several attractive chemical processing approaches which use explosive molecules as chemical feedstock for synthesis to higher value products. The details will not be reported here (Mitchell and Sanner report at this conference on their work on conversion of TNT to high value products) but the idea of using huge quantities of recovered RDX and TNT as starting materials is an attractive option in light of the strong emphasis on waste minimization and resource recovery.

Issues associated with this approach center around generating additional wastes in these conversion processes when waste minimization is the goal. The wastes generated by these

processes and their category (*e.g.* reactive, hazardous, *etc.*) must be determined and weighed against the advantages gained from conversion. Also, the costs associated with these processes must also include cost-avoidance with regard to destruction with next-generation technology, as the assumption is that open burning is not an acceptable means of destruction.

Waste Destruction

Finally, there are circumstances that for safety reasons or cost efficiency destruction remains the only option in dealing with excess energetics. Although it is an exceedingly low cost, safe, and efficient way to dispose of metastable materials, open burning and open detonation is rapidly becoming an unacceptable means of destruction in the United States because of stricter environmental laws. Next-generation technologies which result in environmentally benign emissions (*e.g.* carbon dioxide, water, nitrogen gas) must be developed. Incineration, on a technology basis, is a sound and efficient process. It generally produces emission products within regulatory compliance limits. However, it is expected to be very costly to upgrade some older incinerators to meet constantly stricter emissions requirements. In addition, there is poor public acceptance of this process in the United States as well as licensing difficulties. At some point the cost benefits of operating the incinerator will not favor its use as a means of destruction.

Several technologies have the potential of meeting the next-generation environmental requirements for benign destruction of energetic materials. These include: molten salt, electrochemical oxidation, chemical dissolution, and supercritical water oxidation. These are being developed by the DOE, DoD, and private industry in the United States. Most of these technologies suffer from one disadvantage or another depending on the specific waste form, its physical and chemical character, and whether or not it has low-level or high level radioactive contamination. The fact remains that selection considerations will be based on the needs of the user and the character of the waste forms. Further process development with regard to material introduction, destruction efficiencies, emission type and levels, and operating parameters in general need to be performed on the above technologies as well as others not mentioned to enable the user to determine destruction cost benefits versus alternative process options.

The general characteristics of the waste streams listed below are typical of DOE streams and are not all-inclusive but rather intended to give a broad sense of the types of waste streams the various destruction technologies are expected to address.

- Bulk forms of neat explosive powders.
- Bulk forms of PBXs.
- Energetic material-contaminated liquids (*e.g.* aqueous, nonaqueous, and mixtures), solids, and mixtures of these.
- Radioactive-contaminated energetic materials (low- and high-level).
- Mixtures of radioactive-contaminated energetics and aqueous/nonaqueous liquids.
- Mixtures of radioactive-contaminated energetics and solid and/or liquid hazardous materials.
- Energetic liquids and materials contaminated with these.
- Energetic polymers.

So, the challenge remains in providing the resources for development of environmentally benign destruction technologies and an attendant information base with which to select the appropriate processes.

