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Title:	On the Re-use of TATB in Plastic-bonded Explosives (PBX)
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On the Re-use of TATB in Plastic-bonded Explosives (PBX)

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ABSTRACT

The solid phase, insensitive molecular high explosive, triaminotrinitrobenzene (TATB), is uniquely suited to meet the safety expectations of a nuclear weapon main charge. Crystals are formulated with several-percent polymeric binder to make plastic-bonded explosive (PBX) molding powder prills; then consolidated with heat and pressure and machined into precision components. The first TATB-based PBX components were introduced into the United States (U.S.) nuclear stockpile in 1979 and current national policy trends toward replacing conventional high explosives with insensitive TATB-based PBX materials in main charge components.

However, TATB is expensive to synthesize and budgets for refurbishing the nuclear stockpile are declining. However, TATB is expensive to synthesize and budgets for refurbishing the nuclear stockpile are declining. This presentation reviews options for re-using formulated TATB that were investigated in the past and makes recommendations regarding the viability of these options for the future. In summary, soft technical arguments can be made for and against the use of 50% recycled material in plastic-bonded explosives for the U.S. nuclear stockpile depending on the specific application requirements. It seems to the authors that decisions about the future use of recycled PBX are more likely to be based upon economic considerations.

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Introduction

- The solid phase, insensitive molecular high explosive, triaminotrinitrobenzene (TATB), is uniquely suited to meet the safety expectations of a nuclear weapon main charge.
- Crystals are formulated with several-percent polymeric binder to make plastic-bonded explosive (PBX) molding powder prills; then consolidated with heat and pressure and machined into precision components.
- The first TATB-based PBX components were introduced into the United States (U.S.) nuclear stockpile in 1979 and current national policy trends toward replacing conventional high explosives with insensitive TATB-based PBX materials in main charge components.
- However, TATB is expensive to synthesize and budgets for refurbishing the nuclear stockpile are declining. This presentation reviews options for re-using formulated TATB that were investigated in the past and makes recommendations regarding the viability of these options for the future.

Historical Notes

- **Three compositions of TATB-based PBX have been used in the US nuclear stockpile. The same polymer binder, Kel-F 800®, has been used in all three compositions.**
  - PBX 9502, which incorporates 95 weight-percent dry-aminated TATB
  - LX-17-0, which incorporates 92.5 weight percent dry-aminated TATB
  - LX-17-1, which incorporates 92.5 weight-percent wet-aminated TATB
- **The governing specifications**
  - 13Y-188727 *Material Specification for PBX 9502 Molding Powder* (original issue, 1977, Los Alamos National Laboratory)
  - RM255117 *LX-17 High Explosive Molding Powder* (original issue, 1981, Lawrence Livermore National Laboratory)
  - The efficacy of recycling was studied for both PBX 9502 and LX-17.
  - Current issues of both specifications allow for the incorporation of up to 50% recycled material.

Historical Notes continued

- **Different decisions were made whether to actually use recycled material in specific weapon systems.**
  - The authors were unable to find documentation to establish the basis for the different decisions.
  - All systems using PBX 9502 were designed at LANL and allowed for the use of recycled material.
  - All systems using LX-17-0 or LX-17-1 were designed at LLNL and did not use recycled material.
  - We conclude that the decisions were based more upon differences in institutional philosophy than cogent scientific arguments or even strong, national-level, economic drivers.
- **The TATB feedstock for PBX 9502 and LX-17 was made by a process that is commonly referred to as the Benziger process today.**
  - In recent years, other novel synthesis techniques have been developed but all TATB discussed in this paper refers to TATB made by the historical Benziger process.
  - The observations and recommendations we share are general to the re-use of Benziger TATB whether it was dry- or wet-aminated in its original synthesis.

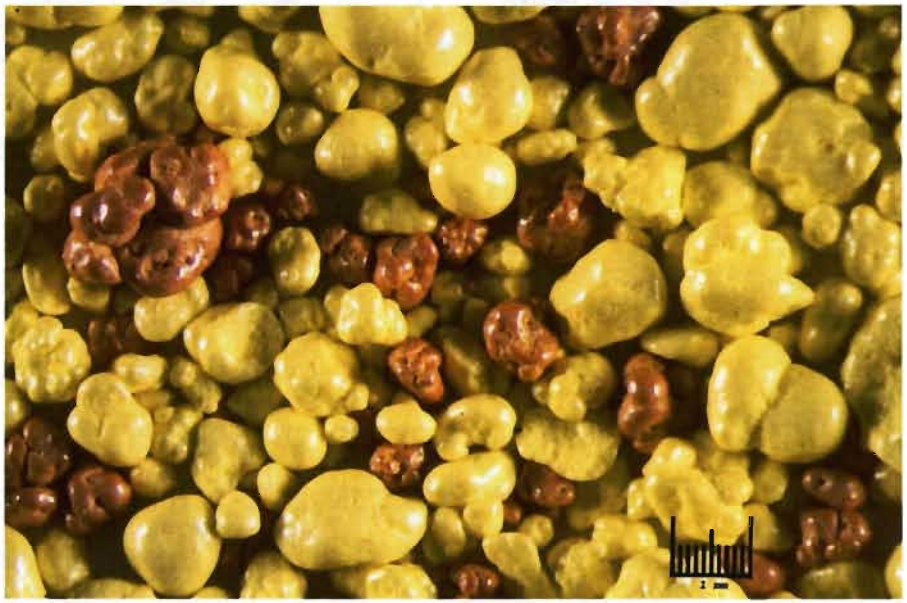
The Original Formulation Process

- **The general process by which TATB particles are agglomerated with a polymeric binder is called formulation. There are a variety of methods for accomplishing this. The specific method used to produce TATB PBX for the U.S. nuclear weapons stockpile is the aqueous (or water) slurry process. The steps can be summarized as follows.**
  - Solid crumbs/pellets of binder are dissolved in a solvent to form a lacquer and set to the side for later.
  - The explosives powder (insoluble in water and lacquer) is added to water in an agitation vessel and dispersed.
  - The lacquer is added to the agitation vessel.
  - Immiscible droplets of lacquer collect most of the explosives particles.
  - The droplets break and coalesce under agitation.
  - The vessel is heated and air sweep or vacuum is used to remove the solvent vapor.
  - As solvent is removed the lacquer droplets become firm, forming smooth-surface granules or prills.
  - The vessel is cooled and the molding powder is dumped into a filter, rinsed, and dried.

Original Molding Powder Prills

PBX 9502

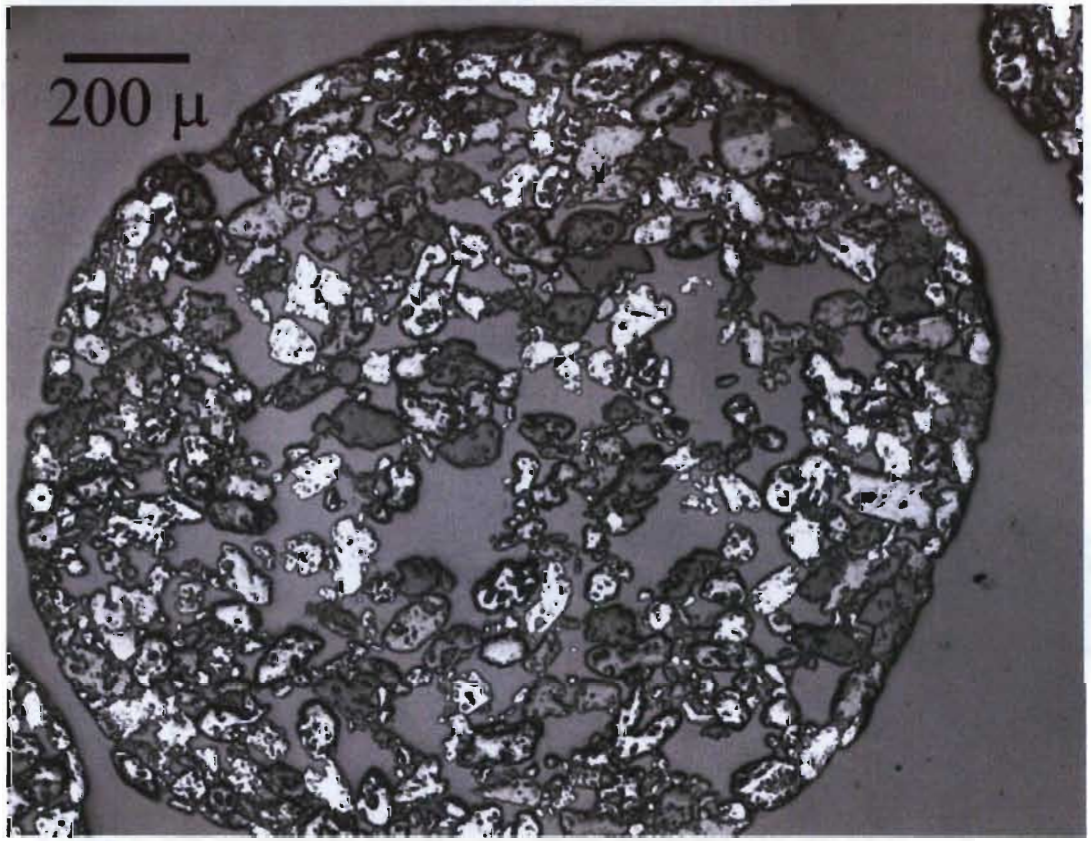
LX-17



One-fifth of lot is colored with dark red dye, per specification.

The Original Formulation Process continued

- The polymeric coating is not explicitly distinguishable but the continuous ring of TATB particles around the periphery suggests that it is most prevalent in that region.
- The goal of subsequent compaction is to eliminate the large void volume within and between prills and to fuse prill boundaries for greater mechanical strength in the final component.
- This end condition for component fabrication becomes the starting point when considering options for re-using TATB.



A microscopic view of a PBX 9502 prill in polished cross-section.

Reversing the Formulation Process

- **Reclaiming TATB**
  - Comminuting/grinding/machining a component
  - Agitating the particles in solvent
  - Separating the resulting lacquer from the insoluble TATB. (The lacquer is discarded.)
  - A practical feed stream for this process is the chips, shavings, or cuttings that would otherwise be treated as waste from machining components to their final shape.
- **Results**
  - Very little residual binder
  - The particle-size distribution is shifted toward smaller particles
  - This TATB may be used as feedstock for a fresh formulation with the same type of polymer or a different one.
  - As required by a Memorandum of Agreement between the Department of Defense (DoD) and Department of Energy (DOE), there is an active project to explore the feasibility of using TATB reclaimed from DOE machining cuttings in a DoD formulation with a different polymer.

Other Approaches to Re-using or Recycling the PBX

- **If the same polymer is to be used in the new formulation, it may not be economical or necessary to separate it from the TATB.**
- **One approach is to simply comminute the component and then compact it into a new charge without re-introducing a solvent.**
  - PBX machining cuttings could be placed directly into a compaction mold to form a new component with 100% recycled PBX.
  - The authors understand that this approach was considered in the past, but we are not aware of any documented effort to investigate it and we do not consider it further in this paper.
- **Another approach is to mix two different feed streams, recycled PBX and virgin TATB, in the same slurry vessel.**
  - The recycled feed stream is generated by agitating the comminuted component (e.g. machining cuttings) in solvent to form a lacquer but no attempt is made to separate the TATB from the binder. The polymer is softened but not stripped.
  - The virgin TATB is added to the vessel containing the recycled PBX and lacquer. Then the standard water-slurry process is followed.

Notes on Terminology

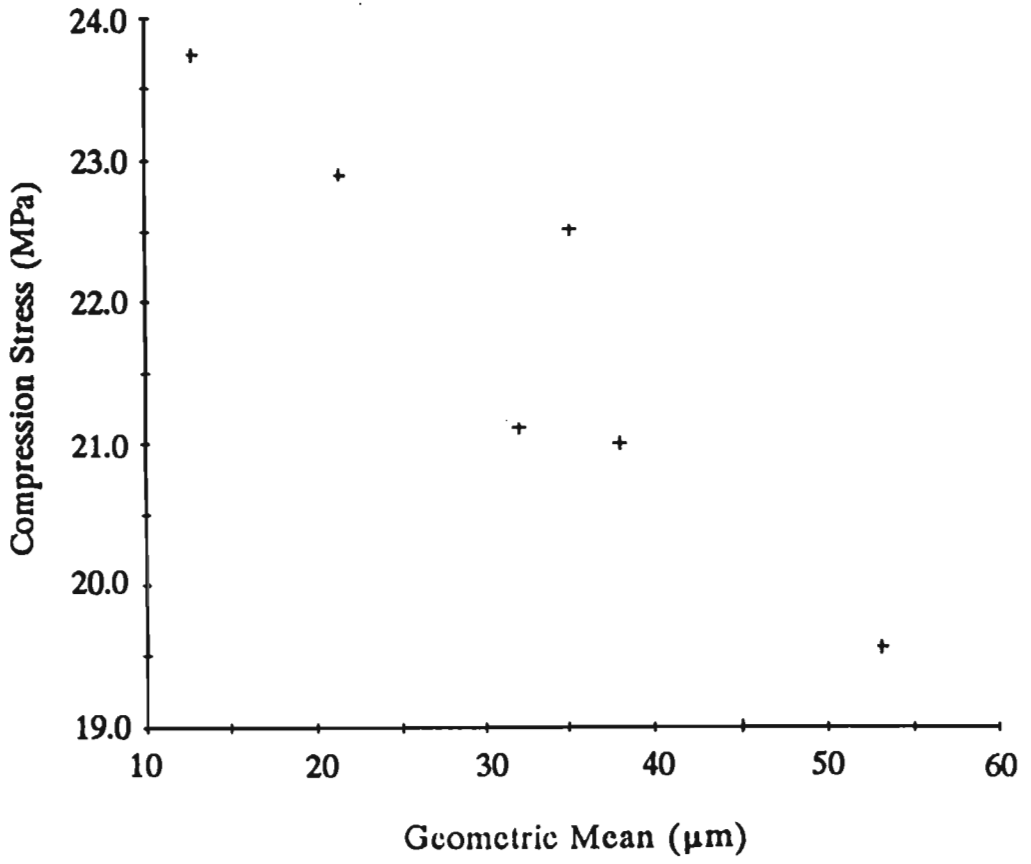
- The terms *reclaimed* and *recycled* are used in this presentation to indicate two different methods of re-using the TATB in a PBX.
- These terms have not have not been used with consistent meanings in reference documents. The investigator is cautioned against tuning into or keying on either term to extract meaning that may not be in the proper context.
- The term *virgin* has been used consistently to refer to material that does not contain any re-used TATB.

Observed Effects of Re-using TATB PBX

- **There is a strong consensus and a supporting body of evidence for these observations regarding the effects of re-using TATB.**
  - The TATB mean particle size is reduced with each processing step that follows original synthesis: formulation, compaction, machining, and subsequent re-use.
  - PBX with 50% recycled material consistently exhibits a modest increase in mechanical strength (tension and compression) and modest decrease in strain or elongation over a wide range of temperatures and strain rates.
  - PBX with 50% recycled material exhibits somewhat improved performance in detonation corner-turning.
  - Sustained planar shock initiation behavior is the same with 50% recycled and virgin PBX 9502 at ambient temperature.
- **Other observations that may not be as well known**
  - A strong correlation between key particle size distribution statistics and stress/ strain can explain the increase in strength and decrease in strain for recycled lots.
  - The residue from compression testing of PBX 9502 with 50% recycled material tends to have more crumbled pieces.

Smaller TATB Increases PBX Compressive Strength

- Duncan prepared six special particle size distributions using TATB with decreasing geometric mean.
- These were formulated into PBX 9502 composition, pressed, machined and tested for compressive strength.
- There is clearly a direct correlation between reduced particle size and increased compression stress.



Smaller TATB Decreases PBX Failure Strain

- **Duncan also conducted a comprehensive sieve analysis of TATB particles reclaimed from 21 different lots of PBX 9502 formulated at the Holston Army Ammunition Plant.**
  - Some lots were100% virgin and some included 50% recycled PBX 9502.
  - For these lots, Duncan showed a strong correlation between Kramer's Modulus and the failure strain.
  - For lots with more fine particles, such as recycled lots compared to virgin lots, Kramer's modulus is reduced and so is the failure strain.
  - This correlation is observed in compression and tension.

More Crumbled Pieces in Compression Failure

- PBX 9502 post-test comparison reported by Thompson.
  - Top row is virgin, fewer pieces.
  - Bottom row is 50% recycled.
  - Size of pieces varies relative to T_g.
  - Surface texture trends are consistent over the range of temperatures and strain rates tested.
- Similar results have been reported by Duncan.
- Effect is attributed to inadequate integration of recycled PBX with virgin TATB and new binder.
  - Can it be corrected with process improvement?
  - Does prill polishing play a role independent of virgin vs. recycled?

Recommendations

- **Soft technical arguments can be made for and against the use of 50% recycled material in plastic-bonded explosives for the U.S. nuclear stockpile depending on the specific application requirements.**
- **The future use of recycled TATB PBX is likely to incur additional costs.**
  - Additional process development (restoration) for this product line.
  - To meet quantity needs, more cuttings are needed as feed-stock
    - Update another specification (13Y-191100 *Material Specification for PBX 9502 Molding Powder Recycled Scrap,* 1983 Original Issue *)*
    - Cumbersome phasing with dismantlement
    - Significant increase in labor, machines, and facility needs
  - Long-term (life of program) cost is increased for surveillance of 2 classes of material
    - Sample selection is more cumbersome
    - Analysis and data reporting are more burdensome
  - Recycled material in stockpile is approximately 20% for PBX 9502, so experience base is less and there are some minor technical questions to be resolved .

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