A Comparison of Different Approaches to Improve Insensitive Munitions in High-Performance Castable Explosives

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Outline

Background of Energetic Partitioning Approach to IM

Formulation and Performance Comparison of Two Explosives

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Discussion of Test Results

Summary and Conclusions

Background

Several different strategies have been used to improve IM performance of energetic formulations, for example:

- Changes in particle size distribution
- Changes in particle morphology (i.e. improved crystal quality)
- Energy partitioning – *approach selected for this study*

Energy partitioning method to reduce violence to IM threats

- Replace part of dominant energetic ingredient with other energetic species
- Energetic species with lowest ignition temperature have lowest energy content
- Reduced temperature at ignition:
  - Delays ignition of principal energetic component
  - Less thermal energy at ignition

Background (cont.)

Successful Energy Partitioning Strategy – Replace Portion of the Energetic Solids and the Inert Binder with an Energetic Binder

Addresses two classes of IM improvements:

- **Cook-off**
  - Energetic binder ignites at lower temperature to provide "soft" ignition
- **Shock**
  - Increased binder component provides extra "cushioning" of energetic solids in impact events
  - Reduced solids content while maintaining energy allows for incorporation of more fine particles while maintaining a castable composition
    - Approach can be effective since flaws in energetic solid particles (particularly large particles) increase shock sensitivity

Formulation and Performance Comparison

Comparison of two high-performance explosives containing a single nitramine

- Formulation 1 (metal driving)
- Formulation 2 (high blast)

Formulation	Formulation 1	Formulation 2
Binder System	10% Inert Binder	22% Energetic Binder
Nitramine	90%	63%
Aluminum	0%	15%
Percent Solids	90%	78%
Relative Density (g/cc)	Baseline	0.095
Relative CJ Pressure (GPa)	Baseline	-1.7
Relative Temperature (K)	Baseline	1021
Relative Measured Detonation Velocity (km/s)	Baseline	-0.4
Relative Expansion Energy at 7.2 V/V_0 (kJ/cc)	Baseline	1.11
Relative Mechanical Energy of Detonation (kJ/cc)	Baseline	3.17

Formulation 2 decreases nitramine level from 90% to 63% compared to baseline composition while maintaining excellent energy

Formulation Sensitivity Comparison

	Formulation 1		Formulation 2	
Sensitivity Test	**Uncured**	**Cured**	**Uncured**	**Cured**
ABL Impact (cm)	21	13	21	3.5
ABL Friction (psi)	>800 at 8 ft/s	>800 at 8 ft/s	25 at 6 ft/s	180 at 8 ft/s
TC ESD (J)	>8	>8	>8	>8
SBAT Onset (°F)	320	307	267	270

Similar and acceptable small-scale sensitivity seen with both explosives

Formulation 2 decreases simulated bulk autoignition temperature (SBAT) by about 40 °F as desired in energy partitioning

Subscale Screening Tests

Two subscale test articles were chosen to evaluate the potential benefit in IM improvement associated with the energy partitioning approach

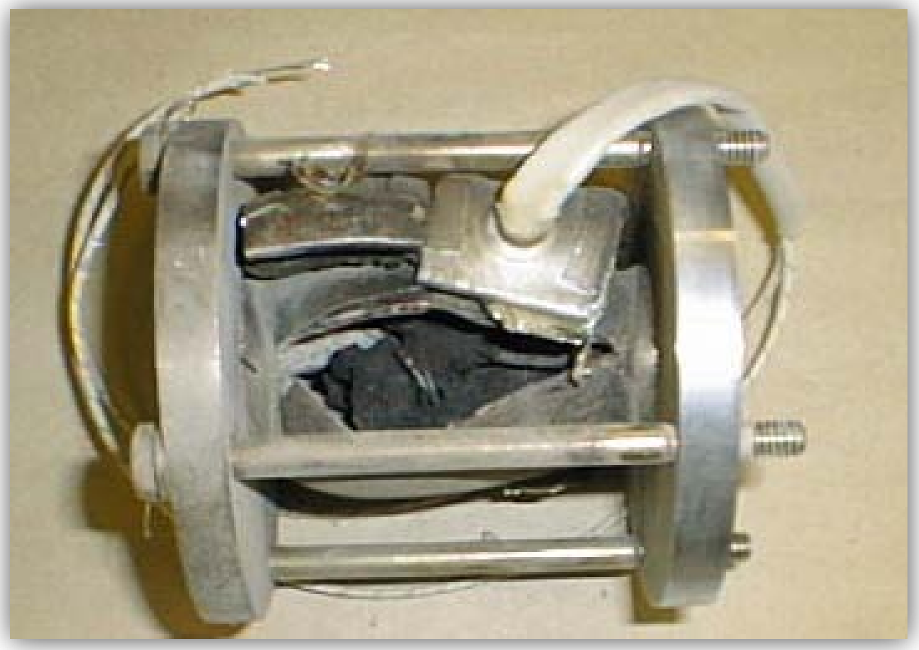
- Variable confinement cook-off test
  - Useful to screen cook-off response of candidate formulations
- Insensitive high-explosive gap test
  - Useful to screen shock response of candidate formulations
- Both tests were initially developed by the U.S. Navy and have been successfully used on multiple programs
  - Formulations evaluated in the study have the required small critical diameter

VCCT Overview

Variable confinement cook-off test was initially developed by researchers at NSWC/White Oak to screen cook-off reaction violence as a function of confinement

Sample is cast into a thin aluminum sleeve that is placed inside a steel sleeve of variable thickness and the entire assembly is bolted into two endplates

Reaction violence can vary from a detonation to a mild burn or pressure rupture as shown below from tests involving two different formulations



VCCT Test Results

- Approximately 60 g explosive
- Heat rate = 6 °F/hr

VCCT				
	Formulation 1		Formulation 2	
Wall Thickness (in.)	Reaction Temperature (ºF)	Result	Reaction Temperature (ºF)	Result
0.030	313	Burn	281	Deflagration
0.045	313	Burn	284	Explosion
0.060	315	Burn	283	Explosion
0.075	313	Burn	---	---
0.090	313	Pressure rupture	---	---

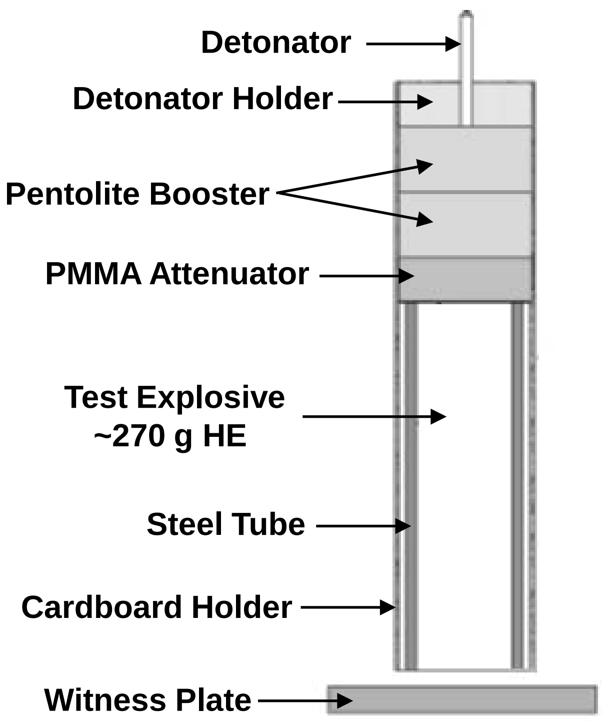
Formulation 2 exhibited more violence despite lower ignition temperature!

IHE Gap Test

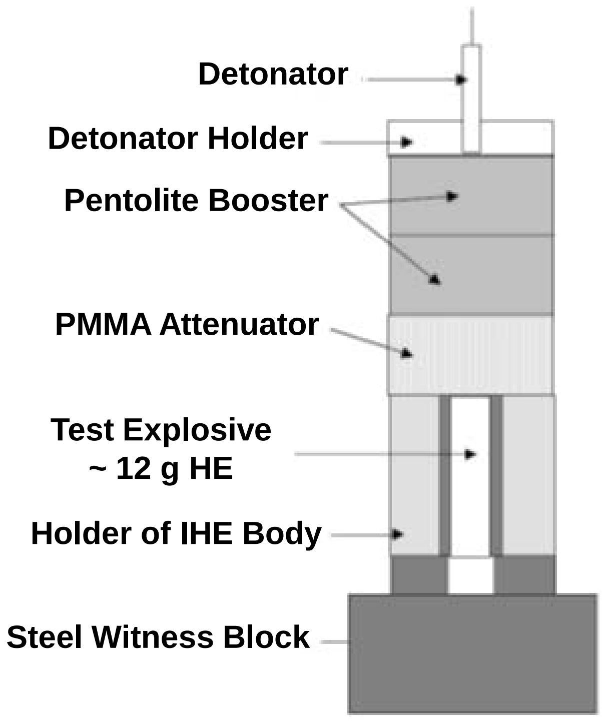
The insensitive high-explosive gap test was also developed at NSWC/White Oak

It was designed to provide researchers the ability to screen explosives for shock sensitivity using less material

- Works very well for explosives with small critical diameters



LSGT Card Gap



IHE Card Gap Setup

Shock Sensitivity (Card Gap)

Card gap testing was performed on both compositions

- Formulation 1 testing used the standard LSGT
- Formulation 2 testing used the IHE gap test

Forumulation 1		Formulation 2	
LSGT Card Gap (cards)	**Initiation Pressure (Kbar)**	**IHE Card Gap (cards)**	**Initiation Pressure (Kbar)**
160	34.0	205	19.6

Formulation 2 was determined to be significantly more sensitive despite the lower levels of a common nitramine!

- Results are similar to Comp B or LX-14

Discussion of Test Results

We postulate that the principal enhancement in IM sensitivity is caused by the energetic binder system in Formulation 2

- Aluminum content has small effect on explosives similar to Formulation 1 which use the identical binder system

Formulation	Formulation 3	Formulation 4
Binder	11% Inert Binder	11% Inert Binder
Alternate Nitramine	74%	89%
Aluminum	15%	0%
Percent Solids	89%	89%
VCCT at 0.060 in. Wall Thickness	Pressure rupture	Pressure rupture
Slow Cook-off 3.2 in. Generic Shaped Charge Units	Burn	Burn
LSGT (cards)	175	177

The inert binder system used in Formulation 1, Formulation 3 and Formulations 4 has produced exceptional IM and performance in high nitramine content explosives

- Binder technology has also been successfully demonstrated in formulations using insensitive high explosive ingredients

Summary and Conclusions

Energy partitioning evaluated in high-performance explosives

- Nitramine reduced from 90% to 63% by use of energetic binder and aluminum
- Lower solids nitramine formulation was found to be significantly more sensitive in VCCT and card gap testing – energy partitioning does not work in this system
- We postulate that the increase in sensitivity is due to the energetic binder system in this class of explosives

The use of subscale tools, VCCT and IHE gap, greatly improved our ability to screen the IM performance of a new composition without incurring substantial cost

Data generated in this study provides additional evidence that the inert binder system provides unique IM advantages in explosives with high nitramine content