Advances in Cast Cure Explosives

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IM testing of 3.2” generic shaped charges:

Bullet and fragment impact performed by General Dynamics Ordnance and Tactical Systems under contract to ARDEC

Fast and slow cookoff performed by National Technical Systems’ National Ordnance, Munitions, and Environmental Test Center under subcontract to General Dynamics

Outline

Objective and approach

Performance

Processing

Subscale Insensitive Munitions (IM) testing

- **Shock sensitivity in LSGT**
- **Slow cookoff in VCCT**

IM testing in 3.2” generic shaped charge warheads

- **Bullet impact, fragment impact, slow cookoff, fast cookoff**

Summary

Objectives and Approach

Objectives: Develop new cast cure explosives that meet the following criteria:

- **Improved performance over PBXN-110 (for HMX formulations)**
- **Equivalent or better IM response than PBXN-110**

Approach: Use a proven binder system which has given good IM and processing properties

•Formulate DLE-C051 to exceed PBXN-110 for metal-driving applications

- **Formulate DLE-C050 to exceed PBXN-110 performance for dual purpose applications – metal driving and blast**
- **Formulate DLE-C053 to provide best cost and performance balance**

Theoretical Performance

Cheetah performance prediction comparison to PBXN-110:

- **DLE-C051 has 4.5% increase in Energy @V/V_0=6.5**
- **DLE-C050 has 31% increase in total mechanical energy (blast)**
- **DLE-C053 slightly lower energy than PBXN-110 but still very good**

Formulation	DLE-C050	DLE-C051	DLE-C053	PBXN-110
P_{cj} (Kbar)	247	264	231	249
V_d (km/s)*	7.59	7.89	7.58	7.75
CJ Temperature (°K)	4734	3757	3768	3682
Energy @ V/V_o =6.5 (kJ/cc)	8.15	7.22	6.7	6.91
Total Mech Energy (kJ/cc)	11.46	9.10	8.6	8.77

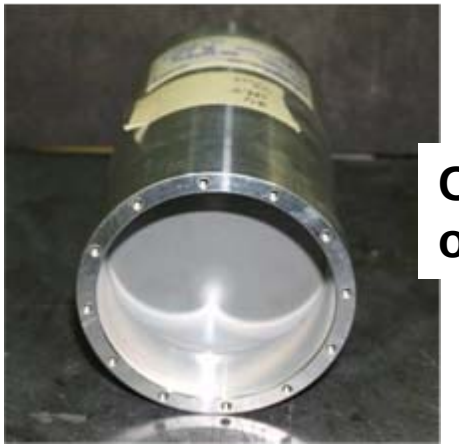
Processing

One of the primary goals in the development of new castable explosives is to optimize processing

Factors to consider include:

- **Ability of binder to wet solids**
- **Final mix viscosity**
- **Flowability of explosive through typical casting tooling**

Excellent flow of mixes and good casting quality



Cast surface of DLE-C050

Shock Sensitivity

Large Scale Gap Tests (LSGT) conducted

- **Sensitivity similar to PBXN-110**
- **DLE-C053 used standard solid explosive**
  - Opportunities to further improve shock sensitivity may be possible through the use of specially prepared material

Formulation	Go/No-go # Cards
DLE-C050	173/175
DLE-C051	176/177
DLE-C053	175/176

Slow Cookoff (VCCT) DLE-C050

Relatively mild VCCT reactions were observed

- **Sample heated at 6 °F/hour.**
- **Steel sleeve in two large pieces at 0.090” wall thickness**

VCCT Test at 0.090 in. Wall Thickness

Variable Confinement Cookoff Testing of DLE-C050		
Wall Thickness (in.)	**Reaction Temperature (ºF)**	**Reaction Level**
0.030	359	burn
0.045	333	pressure rupture
0.060	360	pressure rupture
0.075	367	pressure rupture
0.090	342	deflagration

Slow Cookoff (VCCT) DLE-C051

Relatively mild VCCT reactions were observed

- **Sample heated at 6 °F/hour**
- **Steel sleeve in three large pieces at 0.090” wall thickness**

VCCT Test at 0.090 in. Wall Thickness

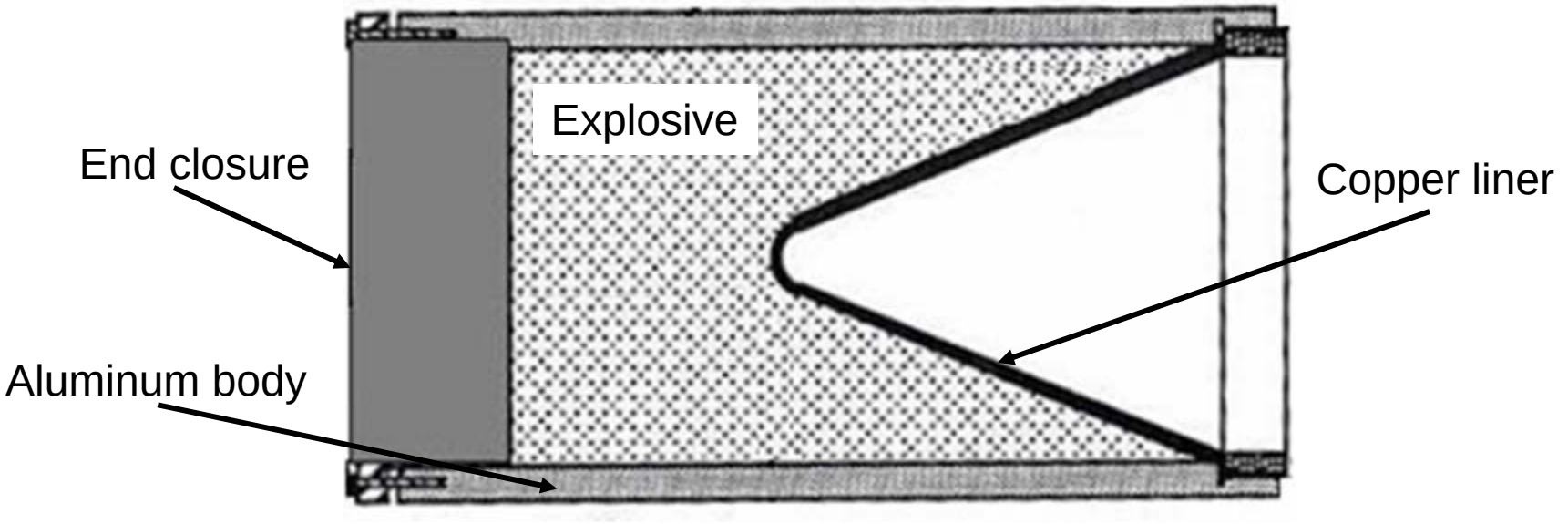
VCCT of DLE-C051		
Wall Thickness (in.)	**Reaction Temperature (ºF)**	**Reaction Level**
0.030	360	pressure rupture
0.045	357	pressure rupture
0.060	358	pressure rupture
0.075	355	deflagration
0.090	371	deflagration

IM Testing in 3.2” Generic Shaped Charges

Device loaded with approximately 2 lb of explosive

Bullet impact, fragment impact, slow cookoff, and fast cookoff performed

Only DLE-C050 and DLE-C051 tested at this time



Schematic of Generic 3.2” Shaped Charge

Bullet Impact Testing of 3.2” Generic Shaped Charges

Single 50 caliber armor-piercing bullet targeted 5.75” from liner end

Test Monitoring
- Over pressure gages
- High speed digital video
- Standard video
- Witness plates
- Velocity screens

Warhead Fill	Projectile Velocity	Gage Pressure Readings	Witness Plate Markings	Result
DLE-C050	2865 ft/s	none	none	Type V (burn)
DLE-C051	2846 ft/s	none	none	Type V (burn)

Bullet Impact Testing of 3.2” Generic Shaped Charges

End closures dislodged from main body

Copper liners remained intact

Explosive fill ignited and burned

No debris thrown more than 50 ft

DLE-C050

DLE-C051

Fragment Impact Testing of 3.2” Generic Shaped Charges

Single conical mild steel projectile at ~6000 ft/s

Test Monitoring

- Over pressure gages
- High speed digital video
- Standard video
- Witness plates
- Velocity screens

Warhead Fill	Projectile Velocity	Gage Pressure Readings	Witness Plate Markings	Result
DLE-C050	6087 ft/s	none	none	Type V (burn)
DLE-C051	6110 ft/s	none	none	Type V (burn)

Fragment Impact Testing of 3.2” Generic Shaped Charges

Warhead cases split open by fragment impact

Debris scattered in the immediate vicinity of test stand

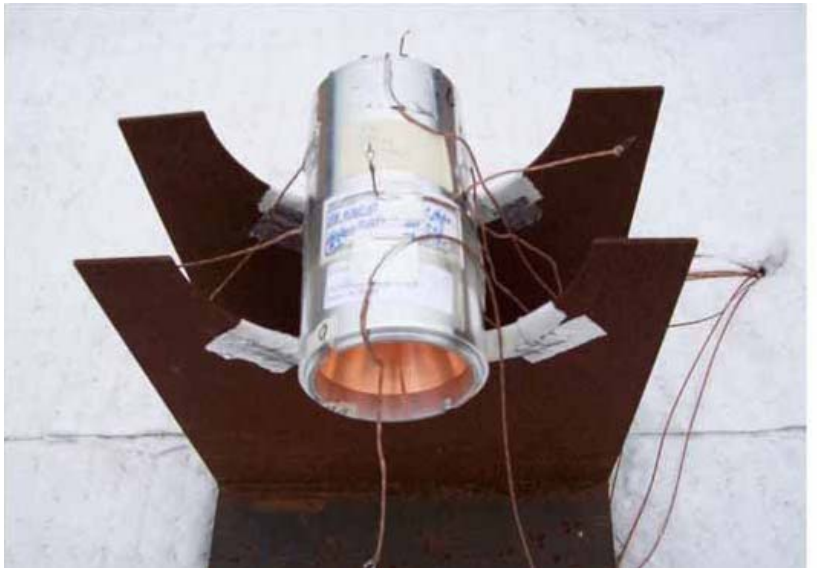
No debris thrown more than 50 ft

DLE-C050

DLE-C051

Slow Cookoff Testing of 3.2” Generic Shaped Charges

Slow cookoff performed at 6 °F/hour heating rate



Test Monitoring

- Over pressure gages
- Standard video inside and outside oven
- Witness plates
- Thermocouples of oven and skin temperature

Warhead Fill	Reaction Temperature	Gage Pressure Readings	Witness Plate Markings	Result
DLE-C050	350.0 °F	none	none	Type V (burn)
DLE-C051	353.4 °F	none	none	Type V (burn)

Slow Cookoff Testing of 3.2” Generic Shaped Charges

Warheads remained essentially intact and lay next to test stand

DLE-C050

DLE-C051

Internal video showed extruding explosive deformed copper liners

Gases vented past deformed liners after ignition

Fast Cookoff Testing of 3.2” Generic Shaped Charges

Fast cookoff performed above fuel basin containing 500 gallons of kerosene

Test Monitoring

- Over pressure gages
- Standard video
- Thermocouples for air temperature near test article

Warhead Fill	Average Flame Temperature	Time to Ignition	Gage Pressure Readings	Result
DLE-C050	1611 °F	33 s	none	Type IV (deflagration)
DLE-C051	1768 °F	13 s	none	Type V (burn)

Fast Cookoff Testing of 3.2” Generic Shaped Charges

Small pieces of burning explosive thrown to 30 ft

Copper liner ejected past 50 ft

DLE-C050 main body found 9 ft from test stand in fuel basin

DLE-C050

DLE-C051 body and liner remained in wire basket and burned (melted) in the fire

DLE-C051

Summary

Two new cast cure explosives developed

- DLE-C050 and DLE-C051
- Compositions have predicted performance better than PBXN-110

Characterization started on a third promising formulation in this family of cast cure explosives (DLE-C053)

- Low cost and high performance

Formulations have excellent processing characteristics

Shock sensitivity similar to PBXN-110

IM response of DLE-C050 and DLE-C051 excellent in 3.2” shaped charges

Warhead Fill	Bullet Impact	Fragment Impact	Slow Cookoff	Fast Cookoff
DLE-C050	Type V (burn)	Type V (burn)	Type V (burn)	Type IV (deflagration)
DLE-C051	Type V (burn)	Type V (burn)	Type V (burn)	Type V (burn)