IM and Qualification Testing of Cast Cure CL-20 Explosive DLE-C038

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OUTLINE

- Background and Objectives
- Theoretical Performance
- Formulation Overview
- IM Response
- Status of Aging and Qualification Testing
- Summary

BACKGROUND AND OBJECTIVES

Delivery packages for precision-guided munitions are often very costly

- High performance warheads increase the cost effectiveness of these munitions

Objective: Develop cast/cure explosive with increased lethality over current state-of-the-art

- 90% CL-20 castable HTPB explosive (DLE-C038)
- Develop robust processing (low end-of-mix viscosities)
- Meet IM requirements
- Perform qualification testing

PERFORMANCE COMPARISON

Cheetah Predictions:

Formulation	DLE-C038 (Castable)	PBXN-110 (Castable)	LX-14 (Pressed)
CL-20	90		
HMX		88	95.5
Estane			4.5
HTPB/Plasticizer	10	12	
Total Solids (%)	90	88	95.5
Density (g/cc)	1.821	1.677	1.834
P_{cj} (Kbar)	330	249	344
Measured V_d (km/s)	8.73 unconfined 9.04 confined	8.39 measured	8.84 measured
CJ Temperature (°K)	4168	3670	3928
Energy @ V/V_o =6.5 (kJ/cc)	8.41	6.88	8.58
Total Mechanical Energy (kJ/cc)	10.24	8.88	10.27

- Compared to PBXN-110, DLE-C038 has 32% increase in CJ pressure and 22% increase in expansion energy at V/V_o =6.5
- Similar energy to LX-14

FORMULATION OVERVIEW

- **Composition uses commonly available sizes of CL-20**
  - No special particle sizes are required
- **Good laboratory scale sensitivity**
  - Friction, impact, ESD, thermal stability
- **New plasticizer used that reduces viscosity and provides excellent mechanical properties over a wide temperature range**
  - Viscosity reduction as much as 90 kP when compared with DOA
- **Robust processing**
  - Over twenty 1-gallon mixes with excellent processing using a variety of material lots
- **Excellent small-scale IM response**

VARIABLE CONFINEMENT COOKOFF TEST (VCCT)

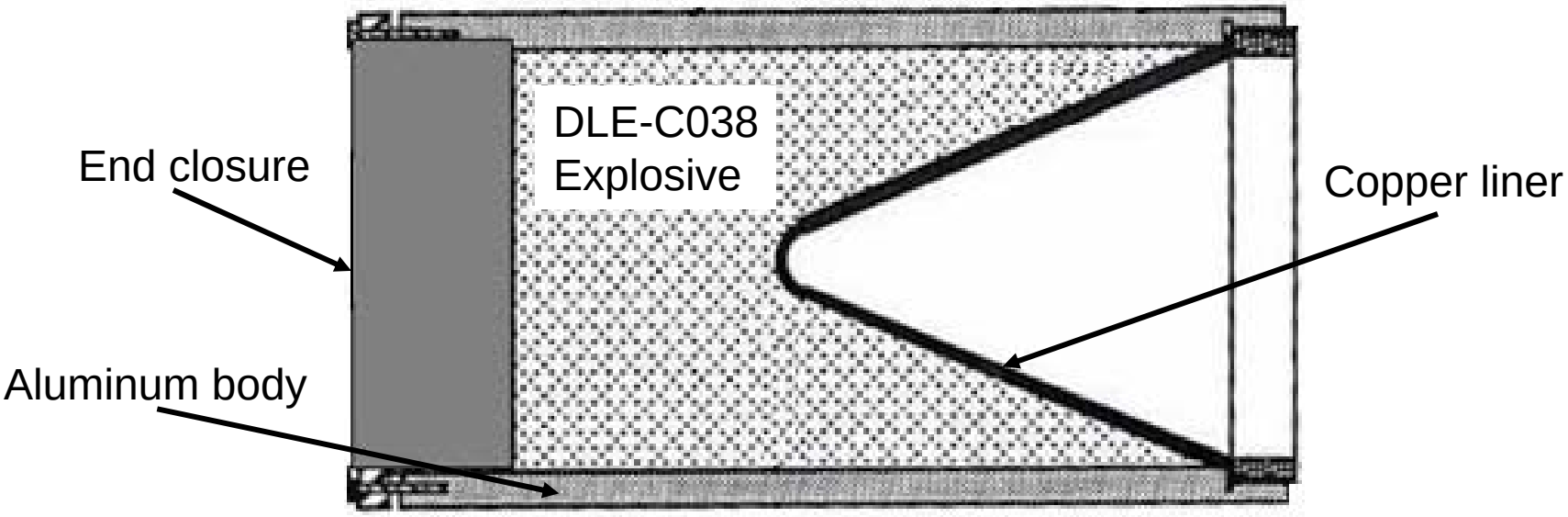
Mild VCCT reactions were observed

- Sample heated at 6 °F/hour.
- Tested up to 0.090” wall thickness

VCCT (Two tests except for 0.090 in. wall)		
Wall Thickness (in.)	**Reaction Temperature (°C)**	**Result**
0.030	156/156	burn/burn
0.045	156/156	burn/burn
0.060	157/156	burn/pressure rupture
0.075	156/158	burn/pressure rupture
0.090	156	pressure rupture

IM TESTING OF 3.2 IN. GENERIC SHAPED CHARGES

- Device loaded with approximately 960 g DLE-C038
- Bullet impact and slow cookoff testing conducted according to MIL-STD-2105C (except 1 bullet used)
- Event covered with high speed video (12,500 fps) , regular video, and blast overpressure



Schematic of Generic 3.2” Shaped Charge

BULLET IMPACT OF 3.2 IN. SHAPED CHARGE

50 cal impact at 2800 ft/s

Result – Type IV reaction (pressure rupture)

- Flame visible from entrance and exit hole that quickly died out and was followed by mild burning of explosive fill
- End closure traveled about 200 ft and main body 60 ft (mostly rolling on ground)
- No overpressure

BULLET IMPACT OF 3.2 IN. SHAPED CHARGE

No damage to end closure or copper liner

Only a small crack in the main body that extends from the enlarged exit hole to the edge of the case

BULLET IMPACT HIGH SPEED VIDEO

BULLET IMPACT REGULAR VIDEO

SLOW COOKOFF OF 3.2 IN. SHAPED CHARGE

Electric oven heated at 6 °F/hr

Result – Type V reaction (burn)

- Reaction occurred at oven temperature of 158 ° C (317 °F)
- End closure separated from main body but remained inside oven
- No overpressure

SLOW COOKOFF OF 3.2 IN. SHAPED CHARGE

No damage to main body, end closure, or copper liner

Main body and end closure

Copper liner

SLOW COOKOFF REGULAR VIDEO

QUALIFICATION TESTING

Test plan followed NAVSEAINST 8020.5C

Aging at two conditions for 1 year

- Accelerated aging at 70 °C
- Humidity aging at 25 °C temperature and 30% RH
- Mechanical properties
- Impact and friction sensitivity
- Thermal stability (DSC)
- LSGT
- CL-20 polymorph

AGING-FRICTION SENSITIVITY

No change in friction sensitivity

Aging at 70 °C ABL Friction 50% Point (Method 1021 of MIL-STD-1751A) (lb)					
Material	**0 Time**	**2 month**	**4 month**	**8 month**	**12 month**
DLE-C038 (Lot RH-01-15)	355@8ft/s	363@8ft/s	380@8 ft/s	537@8 ft/s	589@8 ft/s
RDX (Lot 218-7-022)	389@8ft/s	324@8ft/s	427@8 ft/s	324@8 ft/s	427@8 ft/s
DLE-C038 (sealed at ambient temperature)	355@8ft/s				427@8 ft/s

Aging at 38% RH and Ambient Temperature ABL Friction 50% Point (Method 1021 of MIL-STD-1751A) (lb)		
Material	**0 Time**	**12 month**
DLE-C038 (Lot RH-01-15)	355@8ft/s	479@8 ft/s
RDX (Lot 218-7-022)	389@8ft/s	427@8 ft/s
DLE-C038 (sealed at ambient temperature)	355@8ft/s	427@8 ft/s

AGING (cont)

Impact sensitivity - No change in BOE impact

Thermal Stability – No change in DSC onset

CL-20 Polymorph – CL-20 remains in desired ε polymorph as measured with FTIR

Shock sensitivity – Large Scale Gap Test (LSGT) increased from 160 cards to 176 cards when aged at 70 °C

- Still within historical range of PBXN-110

AGING – MECHANICAL PROPERTIES

Formulation hardens at elevated temperature

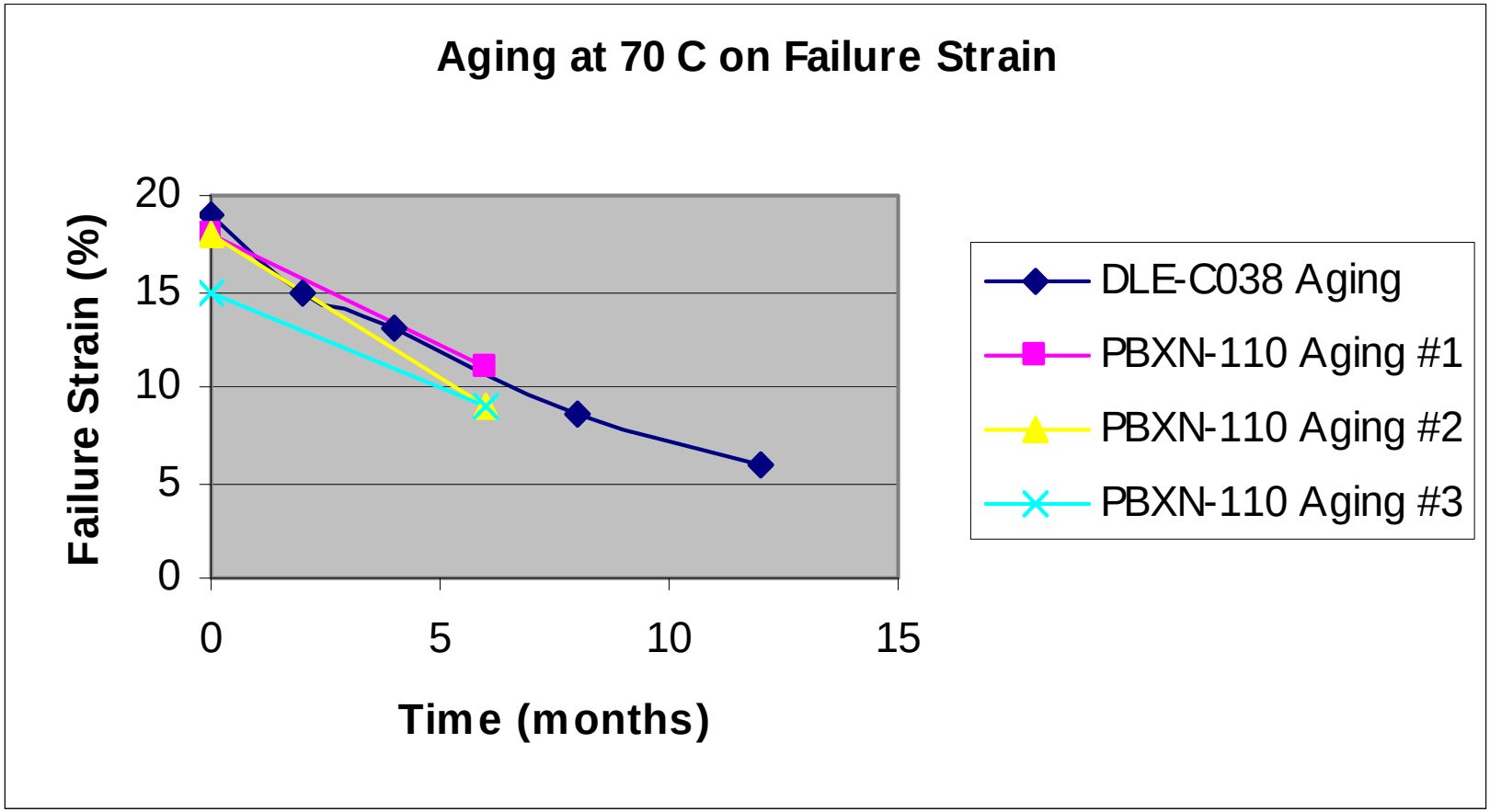
- Similar behavior to PBXN-110

Mechanical properties not effected by humidity aging

Uniaxial Tensile Properties of DLE-C038 Aging at 70 °C (2.0 in/min crosshead rate with JANNAF Class C dogbones at 75 °F)					
	0 Time	**2 month**	**4 month**	**8 month**	**12 month**
Modulus (psi)	701	972	1326	2690	3549
Failure Strain (%)	19	15	13	8.5	6
Max Stress (psi)	105	140	171	228	249

Uniaxial Tensile Properties of DLE-C038 Aging at 38% RH and Ambient Temperature (2.0 in/min crosshead rate with JANNAF Class C dogbones at 75 °F)		
	0 Time	**12 Months**
Modulus (psi)	701	620
Failure Strain (%)	19	19
Max Stress (psi)	105	98

Hardening at elevated temperature similar to PBXN-110



ADDITIONAL QUALIFICATION TESTING

Testing According to MIL-STD-1751A

- Cap Test
- Coefficient of Thermal expansion
- Critical Diameter
- Detonation Pressure – Dent test
- Detonation Velocity
- Vacuum Thermal Stability (VTS)
- Exudation
- Growth (from temperature cycling)
- Ignition and unconfined burning
- Thermal stability (oven test)
- Toxicity (compiled from individual ingredients)

Excellent results seen in all these tests!

Measure Gurney energy with cylinder expansion test

Complete qualification test report

SUMMARY

90% CL-20 cast/cure formulation DLE-C038 developed with excellent theoretical performance

Good processing achieved with new plasticizer

Mechanical properties are good

Sensitivity is excellent for an explosive with such high performance characteristics

Good responses seen in IM testing

- Small scale and 3.2 in. generic shaped charges

Qualification testing of DLE-C038 completed

- No significant unexpected detrimental effects seen in aging

Explosive is ideally suited for use in high value applications requiring maximum performance