

# *High Performance Castable CL-20 Explosive*

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# OUTLINE

- Background and Objectives
- Theoretical Performance
- Processing
- Mechanical and Safety Properties
- IM Response
- Status of 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)

<b>Formulation</b>	<b>DLE-C038 (Castable)</b>	<b>PBXN-110 (Castable)</b>	<b>LX-14 (Pressed)</b>
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
$V_d$ (km/s)	8.73 measured	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

# PROCESSING – PLASTICIZER SELECTION

- Early mixes had high viscosities at 88% CL-20
  - HTPB/IDP and HTPB/DOA binder systems
- New plasticizer found
  - Better wetting of solids and reduced mix viscosity
  - Low CL-20 solubility
  - Cost is low and availability is good
  - No compatibility problems identified
  - Provides for good mechanical properties of the cured explosive at low temperatures

# VISCOSITY REDUCTION WITH NEW PLASTICIZER PL1 AT 88% CL-20

	<b>PL1</b>	<b>IDP</b>	<b>DOA</b>
<b>End of Mix Viscosity</b>	2.4 kp	41 kp	96 kp

- Plasticizer PL1 greatly reduces mix viscosity through improved wetting of solids
- 90% CL-20 formulation DLE-C038
  - PL1 Plasticizer
  - EOM viscosity < 2 kp

# SOLUBILITY OF CL-20 IN PLASTICIZERS

<b>Plasticizer</b>	<b>75 °F</b>	<b>135 °F</b>
PL1	0.0%	0.0%
IDP	1.5%	1.6%
DOA	2% (NWC data)	

- CL-20 is not soluble in PL1
  - Eliminates potential problems of crystal growth during aging or temperature cycling

# SENSITIVITY

<b>Test</b>	<b>DLE-C0380</b>	<b>Class 5 RDX</b>
BOE Impact (50% point) MIL-STD-1751A	73.7 cm	9.6 cm
ABL Impact (50% point) MIL-STD-1751A	355 lb @ 8 ft/s	324 lb @ 8 ft/s
Thiokol ESD	>8 Joules	0.9 Joules

- Impact, friction, and ESD sensitivity are good
- DLE-C038 passed DOT Hazard Classification Testing

# MECHANICAL PROPERTIES

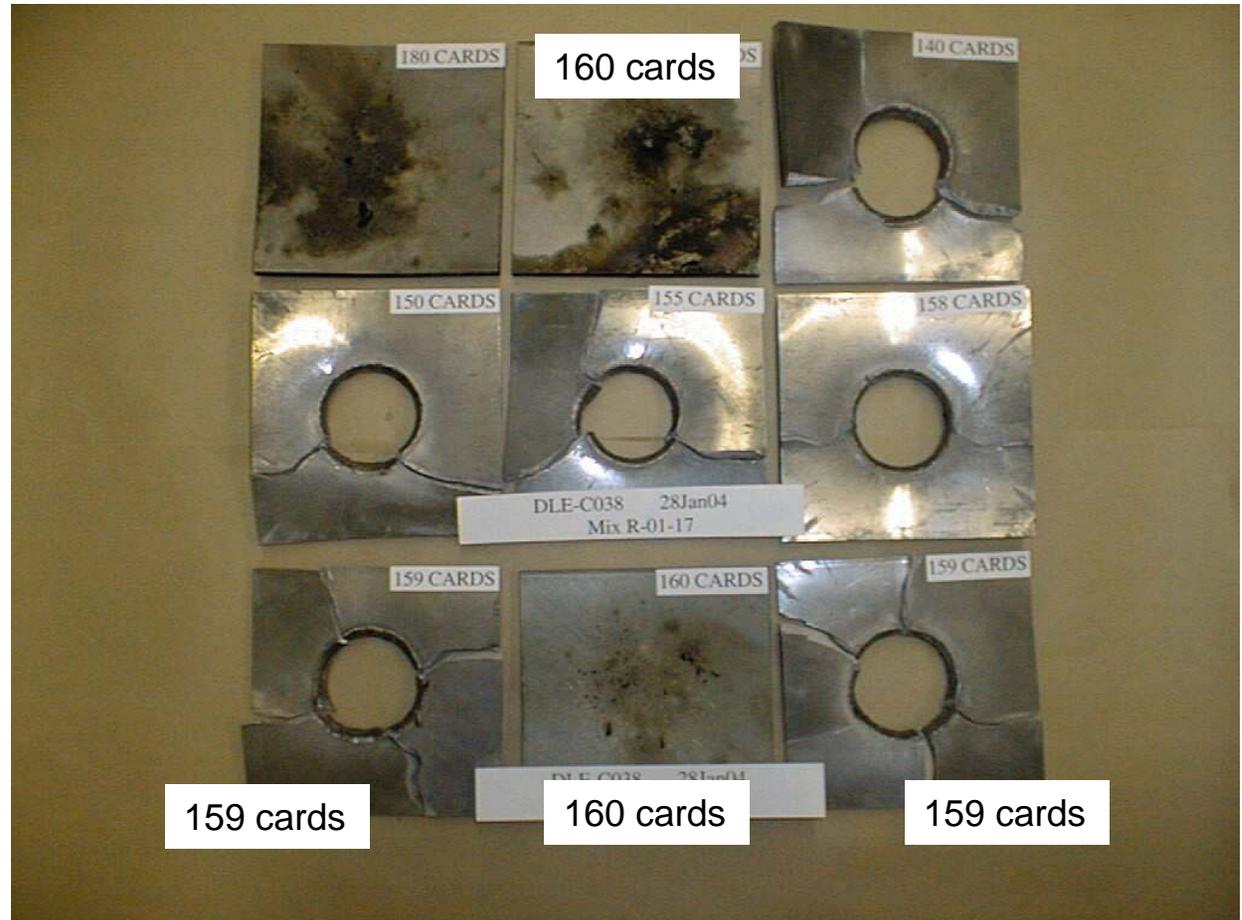
## Uniaxial Tensile Properties of DLE-C038

(2.0 in/min crosshead rate with JANNAF Class C dogbones)

Test Temperature (°F)	Modulus Psi (GPa)	Strain at Max Stress (%)	Strain at Failure (%)	Max Stress Psi (MPa)	Shore A
-40	6183 (0.042)	10	12	503 (3.47)	
75	701 (0.0048)	16	19	105 (0.724)	53
140	374 (0.0026)	20	22	70 (0.483)	

- Good mechanical properties for a high-solids formulation
  - Significantly better stress capability and marginally better strain capability than PBXN-110 at ambient temperature
- Maintains good elongation at low temperatures

# SHOCK SENSITIVITY (LSGT)



- DLE-C038 card gap of 160 cards compares well to the PBXN-110 card gap of 156-178 cards

# VARIABLE CONFINEMENT COOKOFF TEST (VCCT)



- Very mild VCCT reactions were observed
  - Sample is heated at 3.3°F/hour.
  - Burning reactions seen at 0.03, 0.045, 0.06, and 0.075 in. wall thickness
  - LX-14 detonates at a wall thickness of 0.075 in.

# BULLET IMPACT

## (Initial Screening)

- 50 cal impact of 0.5 lb 2.0 in. diameter bare billet
  - No reaction – blast overpressure identical to inert sample

**Debris collected from  
bullet impact test**



# QUALIFICATION TESTING

- Test plan following NAVSEAINST 8020.5C approved and testing underway
- Aging at two conditions for 1 year (8 months completed)
  - 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
- Accelerated aging results after 8 months
  - No change in impact, friction, DSC onset, or CL-20 polymorph
  - Mechanical properties show hardening similar to PBXN-110

## FUTURE PLANS

- Measure Gurney energy with cylinder expansion test
- Perform IM testing in generic shaped charges
- Complete qualification testing

## SUMMARY

- 90% CL-20 cast/cure formulation DLE-C038 developed with excellent theoretical performance
  - Qualification testing of DLE-C038 in progress
- Good processing achieved with new plasticizer
- Mechanical properties are good
- Sensitivity is excellent for an explosive with such high performance characteristics
- Excellent responses seen in small scale IM testing
  - Slow cookoff (VCCT)
  - Bullet impact
  - Shock sensitivity
- Explosive is ideally suited for high value, performance driven applications