RDECOM

Characterization and Comparison of a High Performance CL-20 Explosive

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Prepared for:

2010 Insensitive Munitions/Energetic Material Technical Symposium

October 11-14, 2010 — Munich, Germany

This effort was performed under U.S. Army ARDEC contract 2010-361, INIT233 Agreement No. 01

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Acknowledgments

- **Appreciation is extended to:**

Dr. Kenneth E. Lee of ARDEC

- Overall technical guidance of this advanced technology initiative
- Financial support

Mr. Leslie Bracken of ATK Aerospace Systems

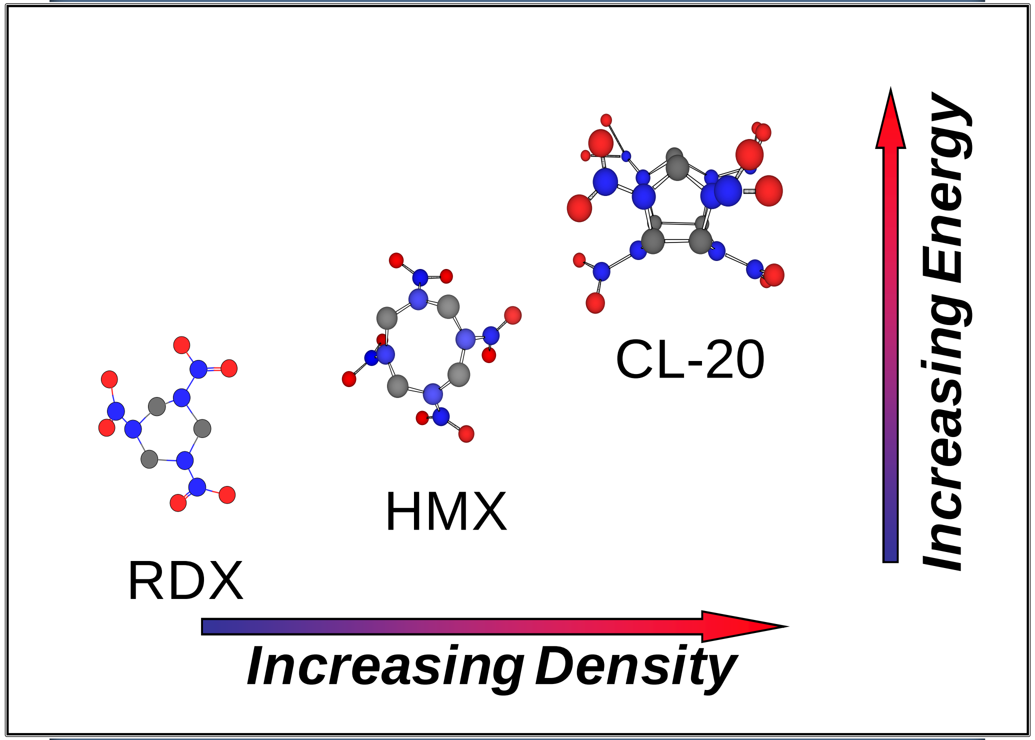
- Program management and task oversight

Outline

- **Introduction / Background**
- **Formulation and Processing Study**
- **Theoretical Performance**
- **Early Characterization Testing**
  - Shock sensitivity
  - Bullet impact
  - Cook-off
- **Process Scale-up and Qualification Plan**
- **Summary and Conclusions**

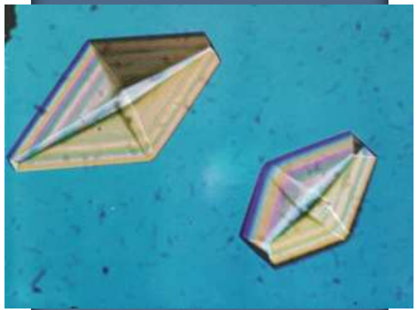
Introduction

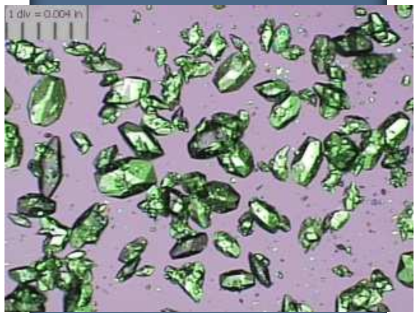
- **When new energetic ingredients are synthesized they are often evaluated theoretically and experimentally in many different formulations**
- **CL-20 is a good example of this pattern as its high density, favorable oxygen balance, and caged structure give it much more energy than HMX or RDX making it attractive in propellants and explosives**

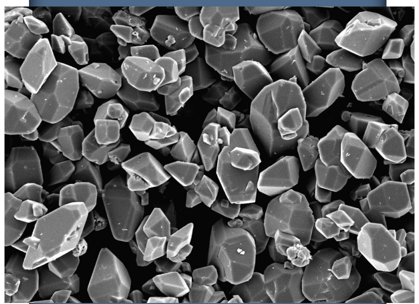


Introduction (cont)

- **Early researchers rapidly determined CL-20 would be attractive for use in cast cure explosives if certain criteria could be met including:**
  - High solids loading
  - Reasonable viscosity
  - Favorable trade between performance and sensitivity
  - Good mechanical properties
- **After evaluating several potential candidate formulations scientists at ATK Aerospace Systems developed a promising castable formulation identified as DLE-C038**







Formulation and Processing

- **DLE-C038 Formulation**
  - 90% solids – Bimodal blend of CL-20
    - Coarse (as synthesized unground)
    - Fine (fluid energy milled material)
  - 10% HTPB binder
    - Includes plasticizer and curative
    - Cured using standard isocyanate
- **Processing**
  - Manufactured using vertical mixers
  - Nominal end of mix viscosity range 2 to 5 kP
    - Robust processing demonstrated using multiple lots of material

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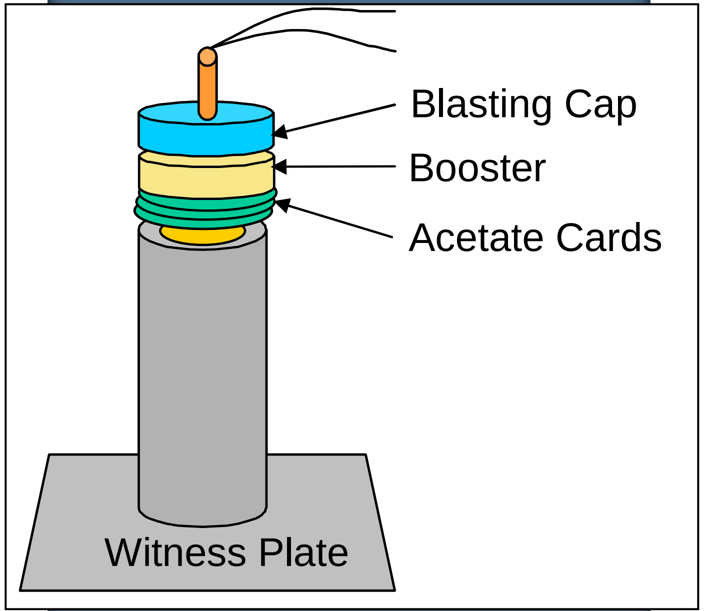
Theoretical Performance

Formulation	DLE-C038 (castable)	PBXN-110 (castable)	LX-14 (pressed)
Nitramine	CL-20	HMX	HMX
Total Solids (percent)	90	88	95.5
Density (g/cc)	1.821	1.677	1.834
P_{CJ} (Kbar)	330	249	344
Measured V_d (km/s)	9.04 Confined	8.39	8.84
CJ Temperature (°K)	4,168	3,670	3,928
Energy at V/V_o = 6.5 (kJ/cc)	8.41	6.88	8.58
Total Mechanical Energy (kJ/cc)	10.24	8.88	10.27

- **DLE-C038 has markedly higher predicted performance than N-110**
  - PCJ 32% higher and Expansion energy at V/Vo is 22% higher
- **Similar theoretical energy to LX-14**

Early LSGT Testing

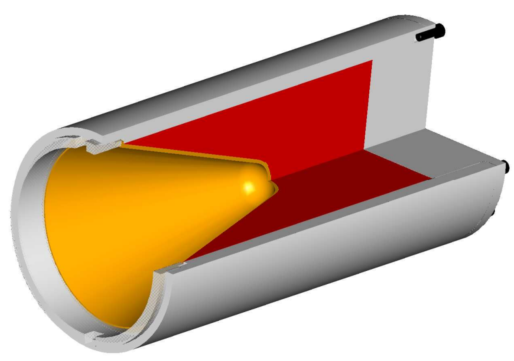
- **Shock sensitivity of DLE-C038 has been measured using the large scale gap test (LSGT)**
- **Test results were very encouraging**
  - Go / No-Go point: 159 / 160 cards (~34 kbar shock input)
  - Standard test methods used
- **Results were duplicated with two different sets of test pipes**
- **Favorable results may be due to high percentage of finely ground CL-20 in this formulation**



Standard LSGT Test Set-up

Bullet Impact Testing

- **DLE-C038 was loaded into generic 81-mm SCJ warheads to evaluate IM performance**
- **Single bullet impact was performed using 0.50 cal round fired at ~850 m/s (2,800 ft/s)**
- **Warhead was placed in a horizontal position**
  - Two arrays of pressure gauges were used to document any overpressure
  - Event was documented using high speed video



Bullet Impact Test Results

- **Excellent results!**
- **No damage to end closure or SCJ liner**
- **Only a small crack in the main body that extends from the enlarged exit hole to the edge of the case**
  - 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

VCCT Testing

- **Cook-off properties of DLE-C038 were initially investigated using the VCCT**
- **Multiple tests at varying confinement have been performed**
  - All tests produced mild cook-off responses

VCCT (two tests except for 0.090-in. wall)		
Wall Thickness (mm / in.)	**Reaction Temperature (ºC)**	**Result**
0.762 / 0.030	156	Burn / Burn
1.143 / 0.045	156	Burn / Burn
1.524 / 0.060	156 – 157	Burn / Pressure Rupture
1.905 / 0.075	156 – 158	Burn / Pressure Rupture
2.286 / 0.090	156	Pressure Rupture

81-mm SCJ Cook-Off

Pre-test View

Post-test View

- **Slow cook-off of DLE-C038 performed in generic 81-mm SCJ**
  - Heating rate 3.3°C/hr
- **End closure separated from main body during testing**
  - Both main body and end closure remained inside the oven during testing
  - Type V response

Close-up Views

Scale-up and Qualification

- **Plans have been developed with ARDEC to scale-up the batch size of DLE-C038**
  - Explosive from larger batches to be used in qualification testing
- **Qualification program will be one year in duration**
- **Testing will examine a broad range of properties**
  - General categories are summarized in table to the right
  - Influence of temperature, time, and humidity will be evaluated
  - Tests will be conducted in accord with AOP-7 or appropriate STANAG

Qualification Test Classification
Stability
Thermal Characterization
Compatibility with Common Materials
Ignition Temperature
Explosive Response
Electrostatic Sensitivity
Impact Sensitivity
Friction Sensitivity
Shock Sensitivity
Other Sensitivity
Chemical, Physical, and Mechanical Properties
Performance Properties
Products of Combustion/Detonation
General Characterization

Summary

- **DLE-C038 is a very promising CL-20 based explosive**
  - Cast cure technology
    - Uses proven HTPB based binder system
    - Low viscosity – easily processed
  - Excellent performance
  - Mild response in cook-off and bullet impact tests
    - Excellent shock sensitivity in LSGT
- **Plans are in place to scale up the processing of this formulation and complete qualification testing**

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