CL-20 PAX Explosives Formulation Development, Characterization, and Testing

NDIA 2003 IM/EM Technology Symposium

By

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Outline

- Material Characterization
- Performance Prediction and Testing
- Formulation and Process Development
- Explosive Characterization
- Summary

Material Characterization

- **The following characterization was performed:**
  - **Scanning electron microscope (SEM) images**
  - **Lattice parameters, strain energy**
  - **Surface analysis: oxide layer, impurities**
  - **Thermal**
  - **Sensitivity (ESD)**
  - **Particle size and surface area**
  - **Compatibility with other explosive ingredients**
  - **Reactivity with water and other processing mediums**

Sensitivity Data
Aluminum Powder

Safety Data	Aluminum Powder
ABL Impact (cm)	80
TC Impact (in.)	>46
ABL Friction (psi)	800 @8 ft/sec
TC Friction (lb.)	>64
TC Confined ESD (J)	8
TC ESD (J)	0.4 (no mass ignition)
SBAT (onset, °C)	>260
DSC (onset, °C)	567

Compatibility Testing with Aluminum

SBAT Compatibility Testing with Aluminum

	Onset Temperature (°C) Heating rate = 13.3 °C/Hour One to one mixtures
Water	51 (no burn)
BDNPA/F	167
CL-20	177
Processing Fluid #1	>260
Processing Fluid #2	>260

ISO-SBAT Time To Exotherm

ISO-SBAT Temperature (°C)	**One to one mixtures Aluminum/Water** (Minutes)
40	120
30	No reaction

Optimization of Aluminized PAX-29

(Cheetah 2.0)

COMPOSITION: Aluminized PAX-29: 3.2% CAB, 4.8% BDNPA/F 92% (CL-20 + Aluminum)	**Density** 99%TMD (g/cc)	**CJ Pressure** (Gpa)	**Det Velocity Dv** (km/s)	**Expansion Energy** @V/V0=6.5 $E_{6.5}$ (kJ/cc)	**Total Mechanical Energy** E_{tot} (kJ/cc)
PAX-29 (0% Al)	1.9575	38.39	9.228	-10.19	-11.741
10% Al	2.0041	36.82	8.937	-10.96	-13.607
13% Al	2.0185	35.99	8.818	-11.12	-14.246
15% Al	2.0283	35.34	8.730	-11.19	-14.704
20% Al	2.0530	33.32	8.477	-11.11	-16.261
22% Al	2.0631	32.33	8.360	-10.99	-17.093
25% Al	2.0784	30.60	8.161	-10.69	-20.812
30% Al	2.101	30.4	8.07	9.65	-19.648

Calculated Performance Comparison

(Cheetah 2.0)

Composition	Al (%)	Density 99%TMD (g/cc)	CJ Press GPa	Dv (km/s)	Exp Energy @V/V0=6.5 $E_{6.5}$ (kJ/cc)	Total Mechanical Energy E_{tot} (kJ/cc)
LX-14 95.5 HMX, 4.5% Estane	0	1.835	34.4	8.80	8.59	10.27
Aluminized Comp A-3 64% RDX, 30% Al, 6% Wax	30	1.824	21.0	7.42	7.60	13.43
PAX-3 64% HMX,20% Al 6.5% CAB, 9.5% BDNPA/F	20	1.859	28.1	8.06	9.59	14.49
PAX-11 94% CL-20 2.4% CAB, 3.6% BDNPA/F	0	1.951	42.5	9.52	10.29	11.84
Aluminized PAX-11 15% Al, 79% CL-20 2.4% CAB, 3.6% BDNPA/F	15	2.023	39.5	8.87	11.23	14.81
Aluminized PAX-11 with AP 25% Al, 30% AP, 39% CL-20 2.4% CAB, 3.6% BDNPA/F	25	2.047	32.2	8.11	10.71	16.24
PAX-29 15% Al, 77% CL-20 3.2% CAB, 4.8% BDNPA/F	15	2.002	38.3	8.77	11.04	14.61

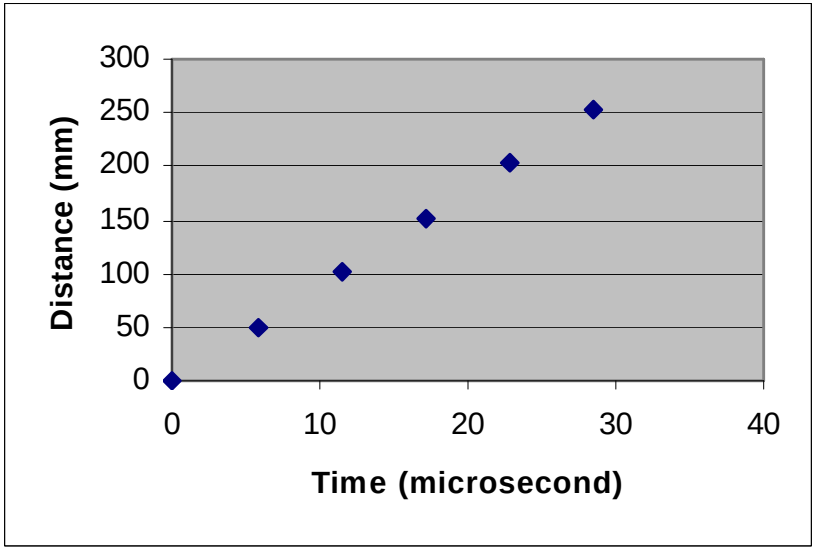
Aluminized Formulations

Ingredients	**Aluminized PAX-11** (Percent Weight)	**PAX-29** (Percent Weight)
CL20	79	77
Aluminum Powder	15	15
BDNPA/F	3.6	4.8
CAB	2.4	3.2
Total Solids (%)	94	92

Aluminized PAX-11 & PAX-29 Detonation Velocity

- **0.5 & 1.0” Diameter Unconfined Pellets**

	Dv (km/sec) Predicted	Dv (km/sec) Actual 0.5” Dia	Dv (km/sec) Actual 1.0” Dia
LX-14	8.80	-------	-------
Al PAX-11	8.87	8.76	8.92
PAX-29	8.77	8.76	8.80

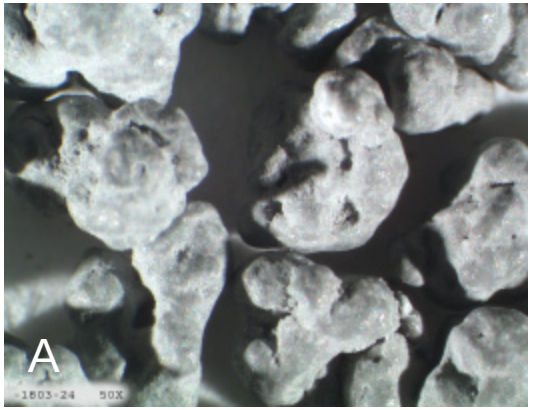


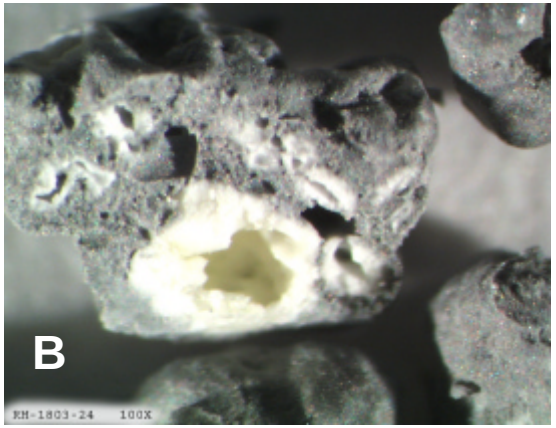
Distance Versus Time for the Detonation Front in the Unconfined Detonation Velocity Test using 1.0-inch Diameter Pellets of aluminized PAX-11

Blast Overpressure

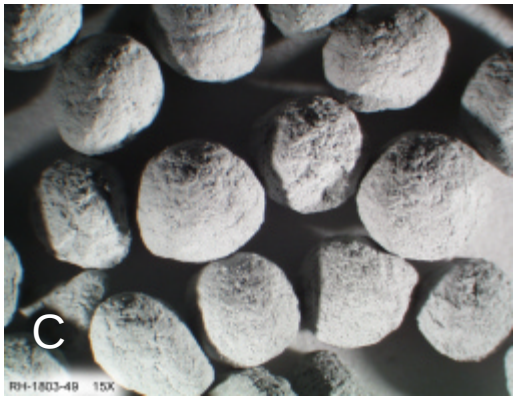
Formulation	Peak Pressure @ 8.5 ft (psi)	Impulse @ 12.5 ft (psi-ms)
LX-14	6.1	5.0
PAX-3	6.3	5.8
Aluminized PAX-11	6.9	6.0
PAX-11	6.3	5.1
PAX-12	6.4	5.1
PAX-22	6.3	5.1
PAX-29	6.9	5.8

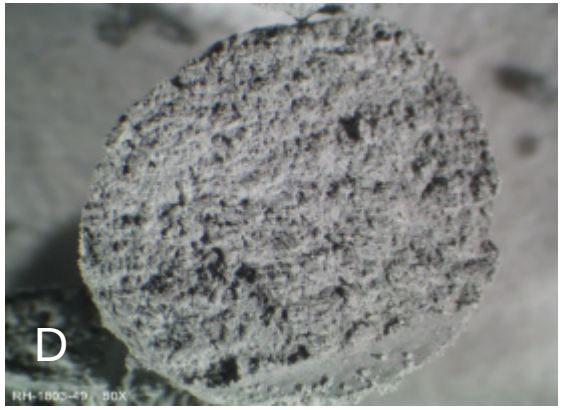
PAX-29 Granule Cross Section





Early Mix
Non-optimized
15x mag
And cross section
50x mag





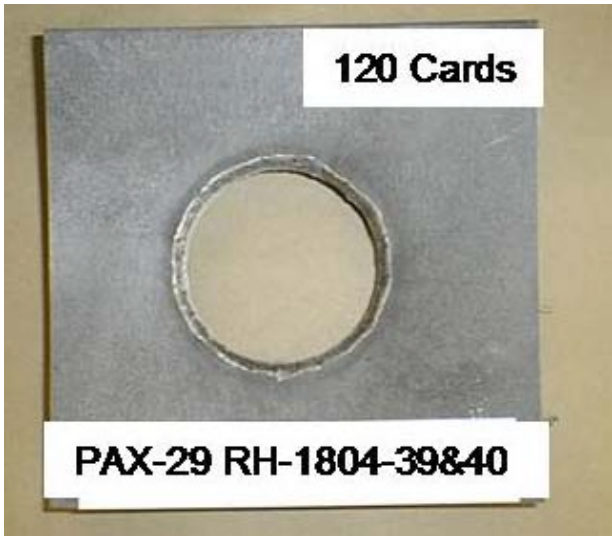
Current mix
Optimized
15x mag
And cross section
50x mag

PAX-29 Sensitivity Characterization

Safety Data	
ABL Impact (cm)	26
BOE Impact (4 in. drop)	1 go, 9 no go
ABL Friction (psi)	320 @ 8 ft/s
TC Friction (lb.)	>64
TC Confined ESD (J)	8
TC ESD (J)	>8
SBAT (onset, °C)	159
LSGT	135 cards

LSGT

- **PAX-29 - Less than 135 Cards**



PAX-29 Machining Study

MACHINE WET AL PAX22C

MACHINE DRY AL PAX22C

PAX-29 Machining Study

						PAX-29 Machining							
							Date: 2/11/2002						
Test	Material and Pellet #	Pellet Density (g/cm3)	Cutting Tool	Cooling Water	Surface speed	Material Outside Diameter	Lathe Speed	Feed Rate	Depth of Cut (target)	Depth of Cut (Actual)	Feed/Speed	Rate of Material Removed	Comments
(#)	PAX-29		(type)		(ft/min)	(inch)	(rpm)	(inch/min)	(inch)	(inch)	(inch/rev)	(in^3/min)	
	Lot RH-1803-43												
1	1	2.018	1" round	NO	210	1.925	416	16.00	0.200	0.202	0.0385	17.53	No Reaction
2	1	2.018	1" round	NO	210	1.520	527	05.30	0.200	0.222	0.0101	04.81	No Reaction
3	1	2.018	1" round	NO	210	1.075	745	02.30	0.200	0.212	0.0031	01.32	No Reaction
4						0.650							
5	2	2.016	1" round	YES	209	1.985	402	16.00	0.200	0.250	0.0398	21.80	No Reaction
6	2	2.016	1" round	YES	210	1.485	540	05.30	0.200	0.212	0.0098	04.50	No Reaction
7	2	2.016	1" round	YES	210	1.060	756	02.30	0.200	0.210	0.0030	01.29	No Reaction
8						0.640							

Summary

- **A new set of aluminized CL-20 explosive formulations were successfully developed for use in multipurpose anti-armor and high blast warhead applications.**
- **PAX-29 was shown to have good sensitivity properties based on the small scale sensitivity tests conducted.**
- **Over 100 pounds of PAX-29 were manufactured for additional testing. (Cylinder expansion testing and warhead testing are planned).**
- **PAX-29 yields a 42% increase in total energy and a 28% increase in expansion energy @V/Vo=6.5 over LX-14.**
- **This combination makes this explosive formulation an attractive fill for multipurpose warhead applications.**