Characterization of LX-14 FEM and PBXN-9 FEM High Energy Explosives

NDIA IMEMTS 2018

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BAE SYSTEMS

Program Overview

- Reduce the shock sensitive properties of established high energy explosives
  - LX-14
    - HMX, Estane Binder
  - PBXN-9
    - HMX, Hytemp ,Dioctyl Adipate (DOA)

- High Nitramine containing explosives utilized to achieve target defeat
  - Exceptional Explosive Energies
  - Tend to be shock sensitive due to nitramine content

- BAE Systems Internally Funded Research Project (IRAD)
  - Integration of IM Technology into legacy formulations
  - Modification of the HMX component
    - Fluid Energy Milled HMX (FEMHMX)

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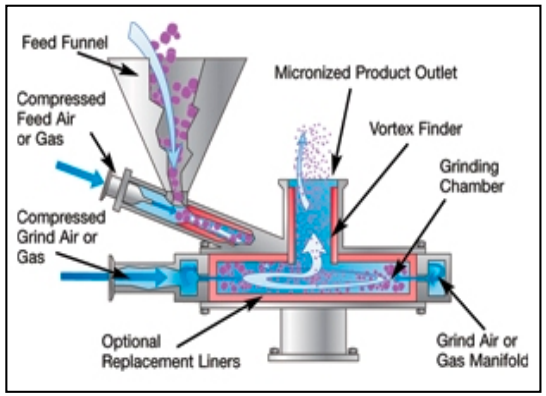
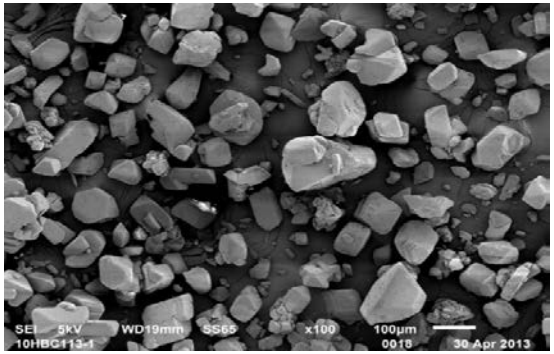
FEM Technology

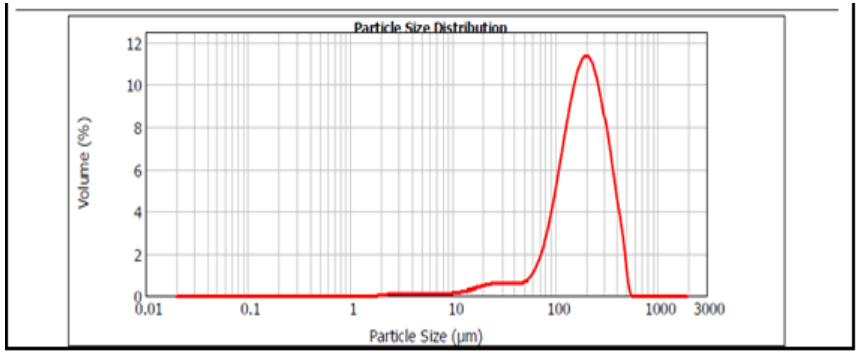
- Traditional mechanical size reduction technology
  - Particles mechanically milled
  - Rough, irregular shapes of produce crystals
- **Innovation of the technology resides in its simplicity**:
  - Compress air employed to move explosive in mill chamber
  - Particle-to-particle impacts reduce size of explosive
    - Ability to reach 1 micron
- No moving parts associated with the energetic processing
  - No sensitized handling of explosives
  - Removal of “pinch points”, extended friction
  - No hazardous collection of explosive dust in system

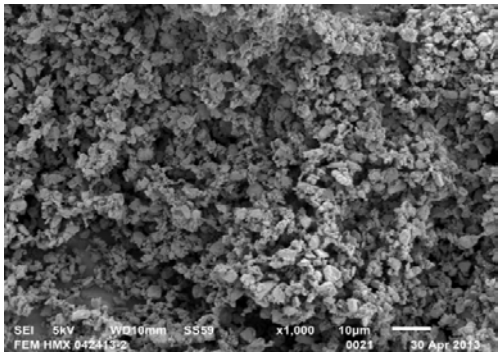


PSD Reduction

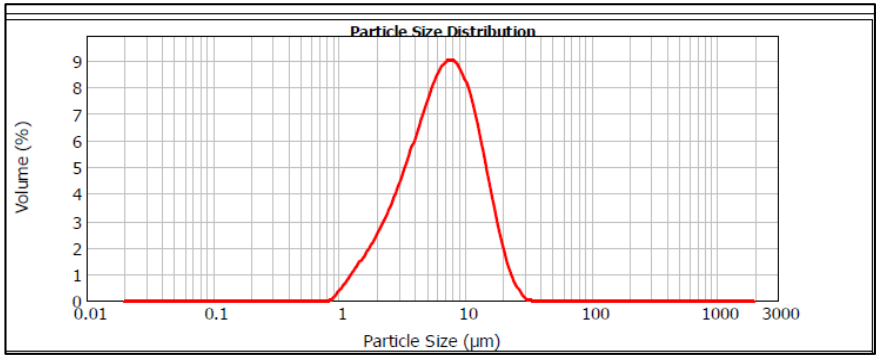


HMX Class 1 (X100)





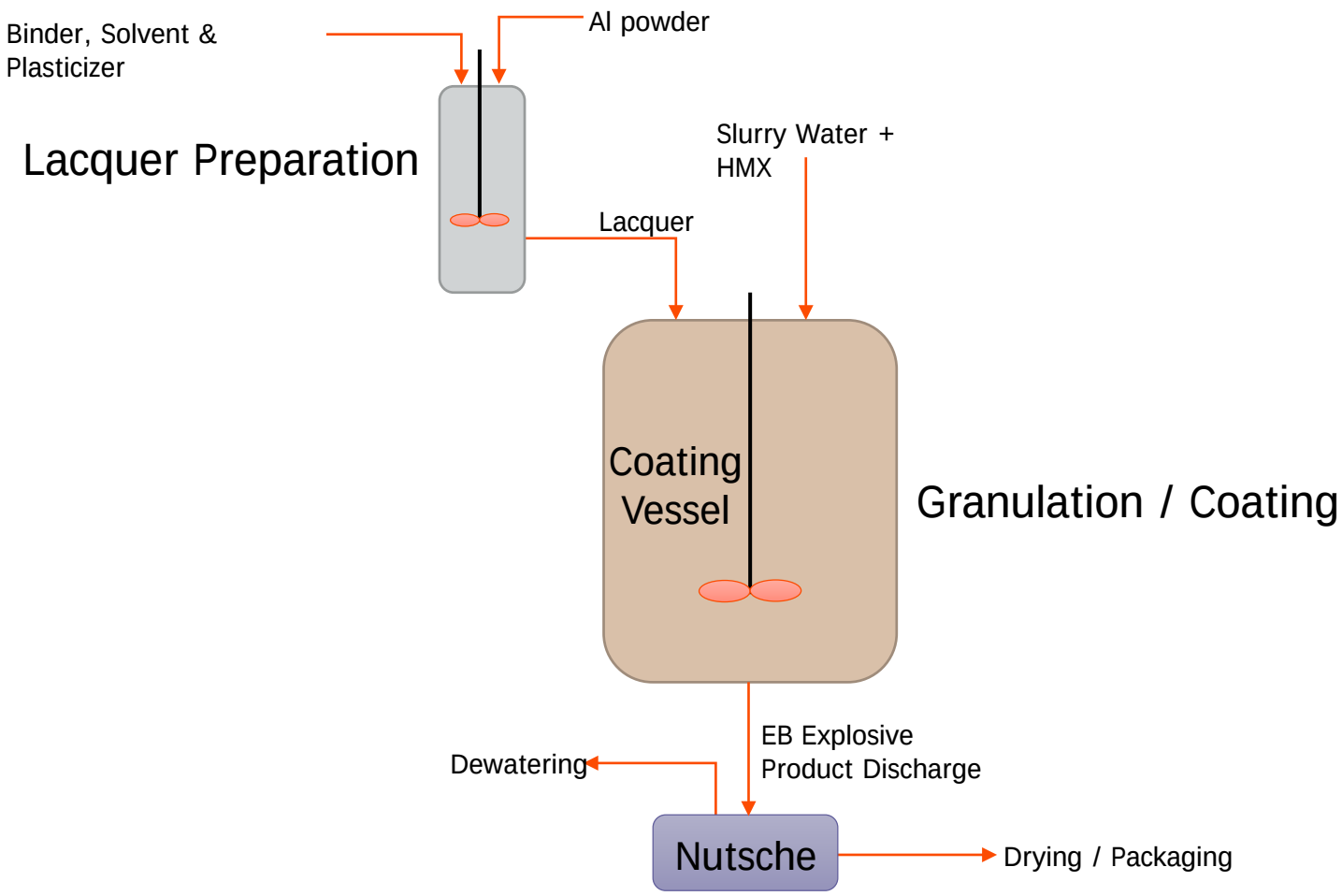
FEM HMX (X 1,000)



PBXN-9 FEM Laboratory Processing

- BAE Systems, OSI (HSAAP)
  - R&D Laboratory Facilities
- Trials Conducted:
  - 1 Liter PBX Slurry Still
  - 10 Liter PBX Coating Still
- HSAAP Slurry Coating Technology
  - HMX mixed in a water system (Slurry)
  - Hytemp/DOA binder dissolved in organic solvent (Lacquer)
  - Lacquer fed into slurry to achieve a precipitation of the binder
  - Solvent recovered via distillation
  - Product cooled, filtered and dried
- Experimental Plan
  - Standard PBXN-9 processing
  - Varied HMX Class 1 / FEM HMX Ratio

Slurry Coat Processing

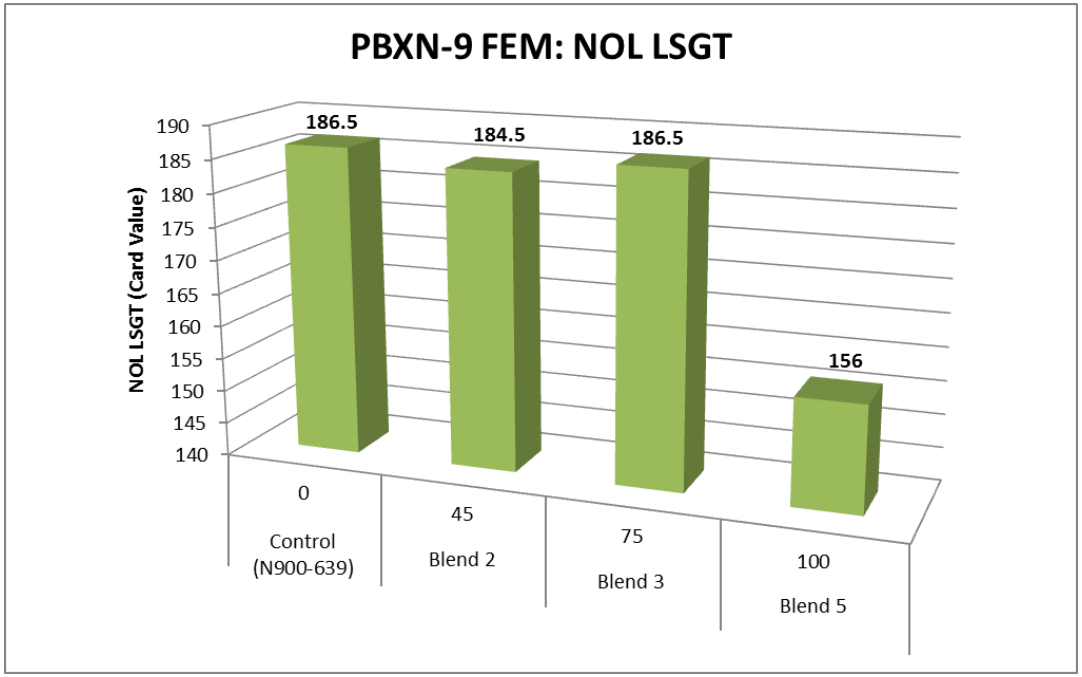


PBXN-9 FEM: Analysis

PBXN-9 with FEM HMX								
Spec	Target					% Passing		
Batch	*% FEM*	*DOA*	*% HMX*	*Hytemp*	*Cup BD*	*6*	*8*	*40*
		5 - 7	*91 - 93*	*1.5 - 3*	*> 0.8 g/cc*	*99 - 100*	*95 - 100*	*0 - 5*
1154-55	25	1.54	96.06	2.40	0.953	100.0	99.3	1.7
1154-56	25	1.51	95.92	2.57	0.945	99.3	98.6	4.2
1154-57	25	5.59	92.26	2.15	0.925	99.8	98.8	1.0
1154-69	25	5.45	92.70	1.85	0.914	100.0	96.9	2.5
1154-70	25	5.47	92.85	1.68	0.940	100.0	98.0	4.5
1154-43	45	6.26	91.77	1.97	0.982	100.0	99.9	1.6
1154-44	45	6.24	91.82	1.90	0.936	99.9	99.1	4.0
1154-45	45	5.78	92.34	1.88	0.954	100.0	98.9	3.2
1154-49	75	5.79	92.24	1.97	0.842	99.0	98.6	3.0
1154-50	75	6.08	91.91	2.01	0.846	99.8	99.3	2.2
1154-51	75	5.89	92.02	2.09	0.877	99.4	98.7	3.6
1154-52	90	6.14	91.79	2.07	0.806	99.8	99.6	6.3
1154-53	90	6.25	91.67	2.08	0.784	99.9	99.8	7.4
1154-54	90	6.16	91.82	2.02	0.780	99.8	99.6	56.2
1154-46	100	6.08	92.02	1.90	0.688	100.0	100.0	56.0
1154-47	100	6.13	91.89	1.98	0.702	100.0	100.0	57.5
1154-48	100	5.96	92.09	1.95	0.711	100.0	100.0	41.0

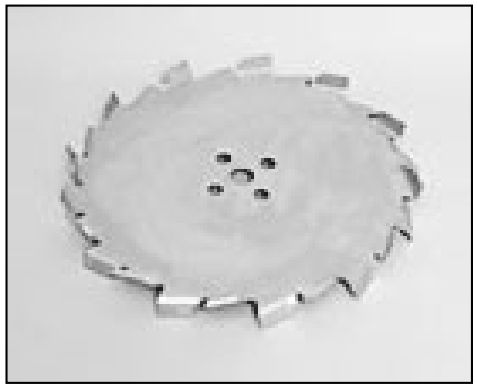
PBXN-9 FEM: NOL LSGT

Batch #	% FEM	DOA	% HMX	Hytemp	Bulk Density	%Pass #6	%Pass #8	%Pass #40	NOL LSGT	Pressed Density	% TMD
		5 - 7	91 - 93	1.5 - 3	> 0.8 g/cc	99 - 100	95 - 100	0 - 5		> 1.73 g/cc	
Control (N900-639)	0	6.30	91.90	1.80	0.83	100	100	0	186.5	1.694	95.2
Blend 2	45	6.24	91.82	1.90	0.94	99.9	99.1	4.0	184.5	1.6756	94.1
Blend 3	75	6.08	91.91	2.01	0.85	99.8	99.3	2.2	186.5	1.6528	92.9
Blend 5	100	6.13	91.89	1.98	0.70	100.0	100.0	57.5	156	1.6487	92.6

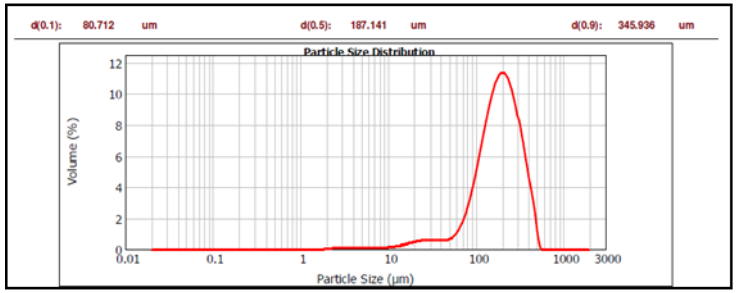


LX-14 Explosive

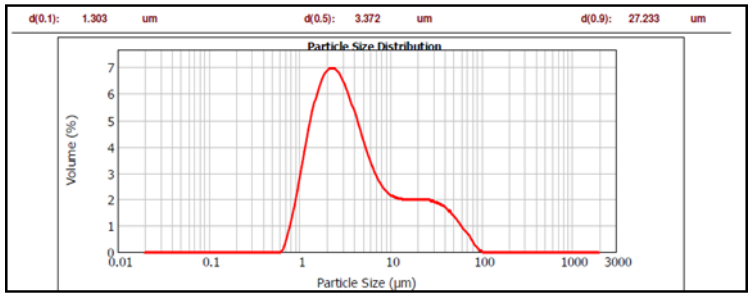
- High Nitramine (HMX) based explosive
- Composition
  - Estane Binder
  - HMX Explosive
  - HMX Class 1
    - HMX Class 2
    - HMX Class 2 (Cowles)
- HMX Cowles Grind
  - Serrated blade induces hydrodynamic shear



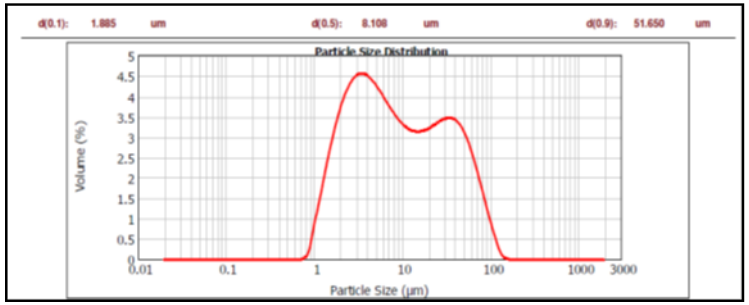
HMX Class 1



HMX Class 2

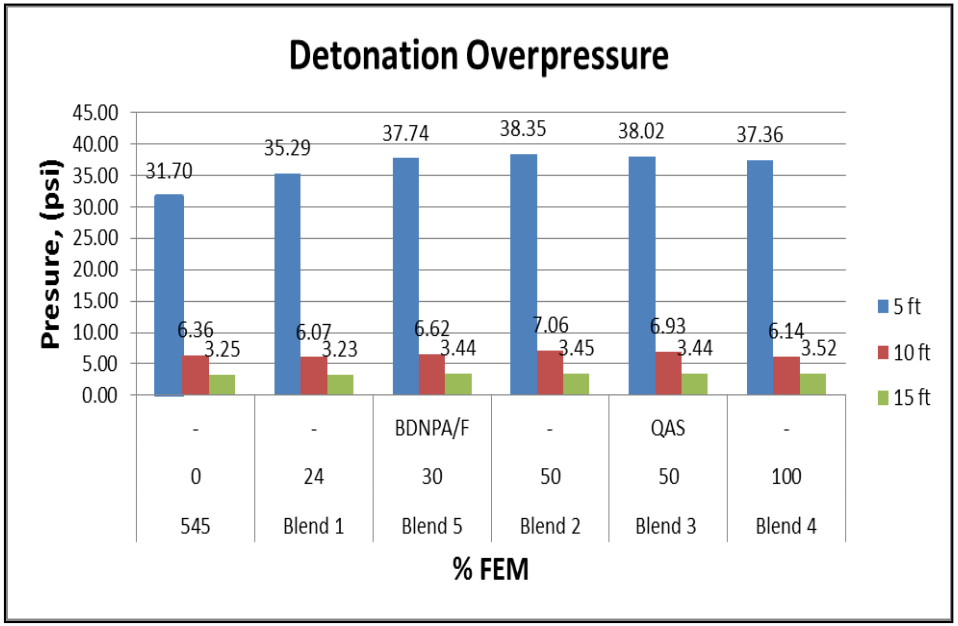


HMX Class 2 Cowles



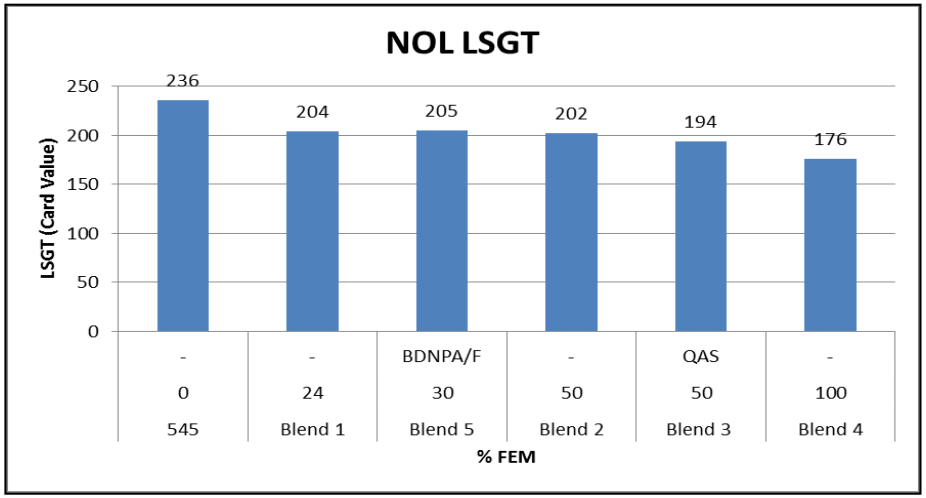
BAE Systems: Explosive Performance

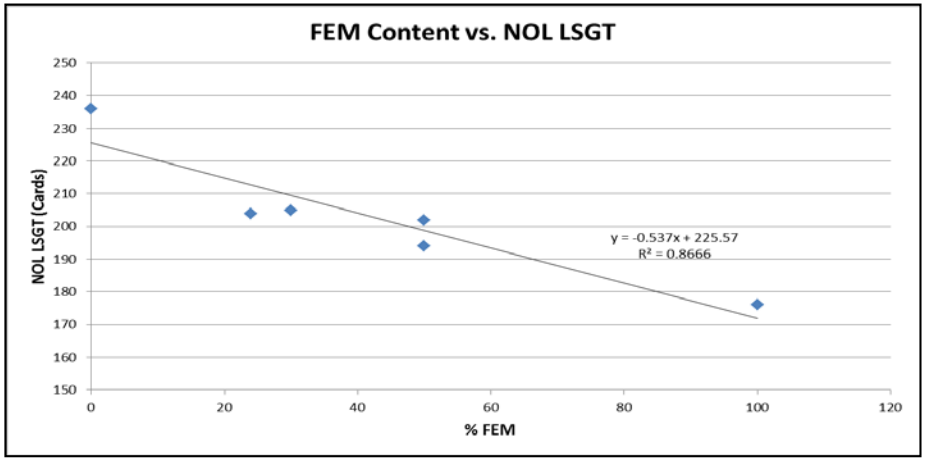
- Blast Overpressure assessment
  - Conducted at BAE Systems (Kingsport, TN) HSAAP facility
- Test Configuration
  - 3 PCB piezoelectric pencil gauge
  - Axial oriented with test charge
    - 5ft, 10ft and 15ft
  - LX140-545 used as baseline comparison of output performance
- Results
  - All experimental formulations exceed pressure of baseline



LX-14 FEM

- Prototype Explosive Formulations Consisted:
  - 0% FEM (Baseline Formulation)
  - 24% FEM
  - 30% FEM
  - 50% FEM
  - 100% FEM
- NOL LSGT
  - Card gap value decreases with increase in FEM content
  - 60 Card Reduction (25.4%)
    - Batch 545 = 236 cards
    - 100% FEM = 176cards





US ARMY: ARDEC Evaluation

- Preliminary press data
  - Increase in density during press cycle
  - Additional decrease in NOL LSGT Card Gap Value

80% FEM

Material:	LX-14 (mod) 80FEM
Lot #:	RDD17E011-059
Date:	5/23/2017
Density:	1.81 g/cc
Shot #:	11-743

Shot	Pellet #s	Gap (in.)	Result (GO/NOGO)	Notes
1	22,33,28	1.80	NO-GO	
2	45,1,35	1.67	NO-GO	
3	31,10,15	1.60	GO	
4	17,39,4	1.64	GO	
5	25,38,14	1.66	NO-GO	N+1
6	44,32,43	1.65	GO	N
7	23,20,16	1.65	GO	N
8	12,41,37	1.66	GO	N+1
9	5,42,29	1.67	NO-GO	N+2
10	6,26,8	1.67	GO	N+2

50% point = N + 1.5 = 1.665 " = 166.5 cards

Data shows ~29.4% in shock reduction as compared to BAE Systems Baseline data

100% FEM

LX-14 (mod) 100FEM	
RDD17E011-056	
5/23/2017	
1.80 g/cc	
11-742	

Pellet #s	Gap (in.)	Result (GO/NOGO)	Notes
1,12,30	2.00	NO-GO	
32,20,2	1.50	GO	
26,5,28	1.80	NO-GO	
44,25,19	1.65	NO-GO	
4,8,23	1.55	GO	
10,18,42	1.61	GO	N
6,36,24	1.64	NO-GO	
33,17,9	1.62	NO-GO	N+1
14,31,37	1.61	NO-GO	N
22,15,3	1.62	GO	N+1

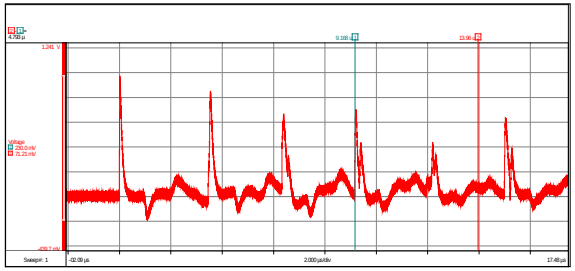
t = N + 1/2 = 1.615 " = 161.5 cards

Data shows ~31.5% in shock reduction as compared to BAE Systems Baseline data

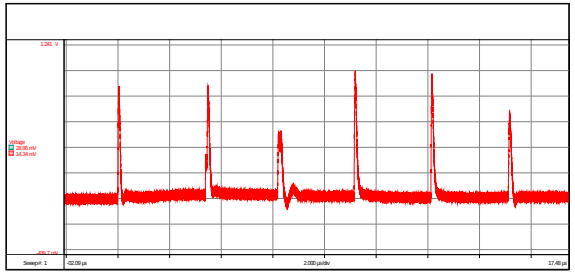
Detonation Velocity: 80% FEM

Nammo Talley

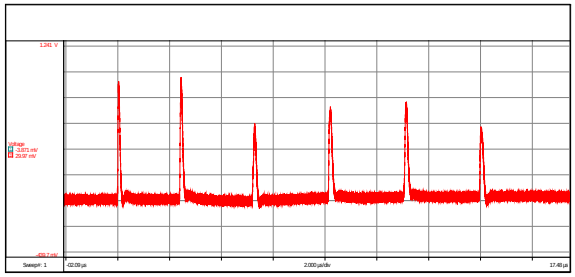
VoD = 8675 m/s



VoD = 8526 m/s



VoD = 8637 m/s



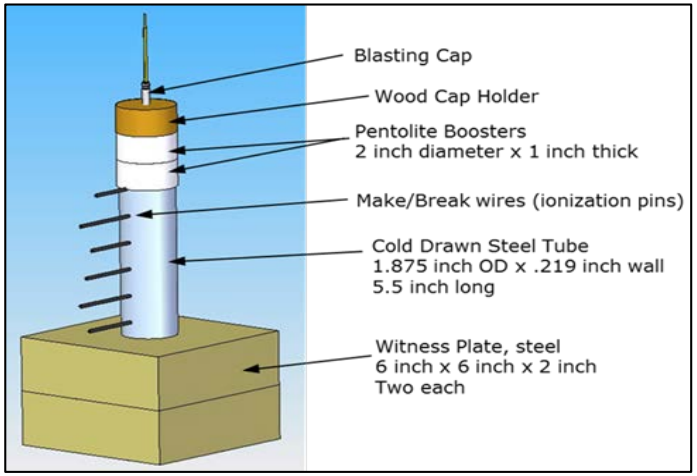
ARDEC

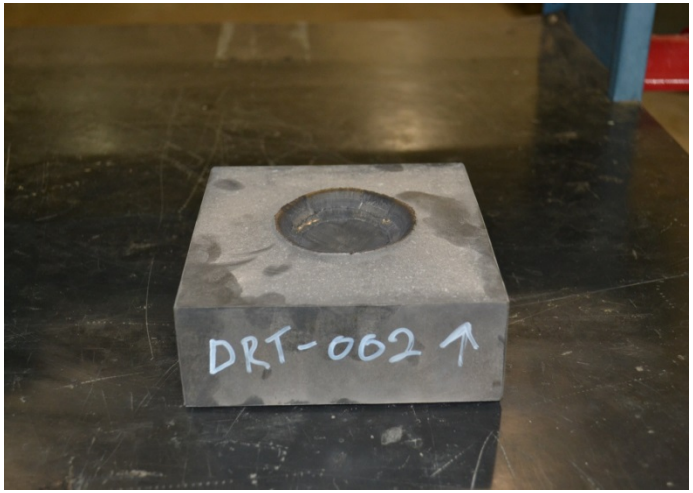
LX-14 (mod) LSDV Testing		
5/26/2017		
Material	Shot #	Det. Vel. (mm/us)
LX-14 (mod) 80 FEM	11-750	8.63
	11-751	8.65
LX-14 (mod) 100 FEM	11-752	8.63
	11-753	8.63

Detonation Calorimetry

Sample	Date	Lot	Net Heat (cal/g)
BAE lx-14 50-50 fem	6/22/2016	Batch 30	1378.03
BAE lx-14 50-50 fem	6/23/2016	Batch 30	1339.99
BAE lx-14 50-50 fem	6/22/2016	Batch 30	1378.03
BAE lx-14 100 fem	6/23/2016	Batch 31	1332.58
BAE lx-14 100 fem	6/23/2016	Batch 31	1339.55

Plate Dent





Nammo Talley

Sample #	Explsoive	Avg Depth (in)
DRT-002*	BAE LX-14	0.47065
DRT-015*	BAE LX-14	0.4749
DRT-016*	BAE LX-14	0.4722
DRT-001	PBXN-110	0.429325
DRT-003	PBXN-110	0.4258
DRT-004	PBXN-110	0.414925

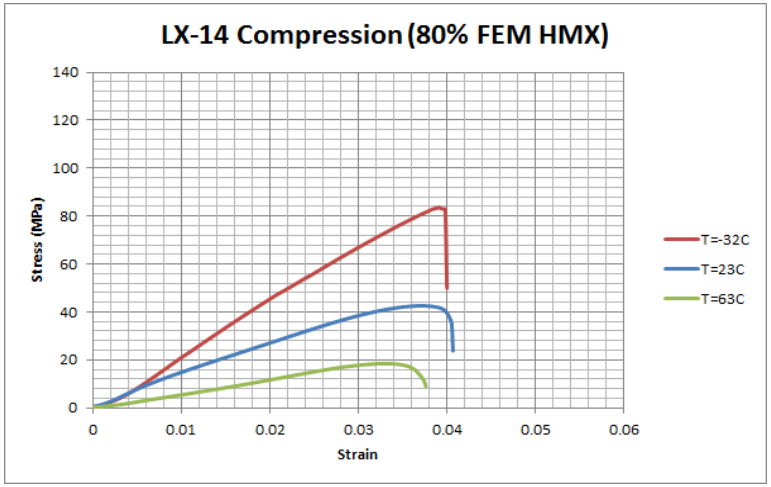
ARDEC

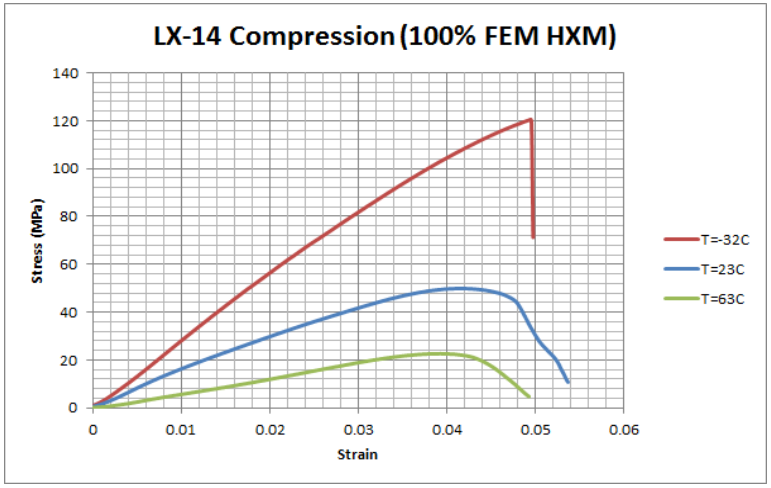
LX-14 (mod) LSDV Testing
5/26/2017

Material	Shot #	Dent (in.)
LX-14 (mod) 80 FEM	11-750	0.419
	11-751	0.419
LX-14 (mod) 100 FEM	11-752	0.421
	11-753	0.415

Uniaxial Compression

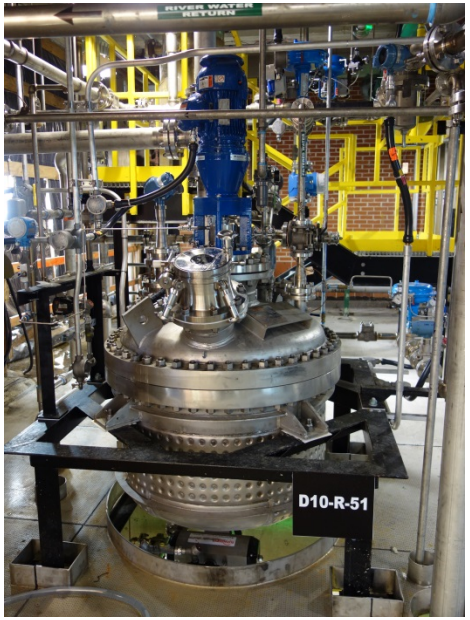
Temp (deg C)	Sample	Yield Stress (MPa)	Strain @ Yield	Modulus (MPa)
63C	80% FEM	18.4	0.0327	631
	100% FEM	22.6	0.039	568
23C	80% FEM	42.5	0.0371	1233
	100% FEM	49.8	0.042	1286
	Ref (Legacy)	19.4	0.028	940
-32C	80% FEM	83.5	0.0395	2333
	100% FEM	120.5	0.0495	2529





HSAAP Pilot Plant

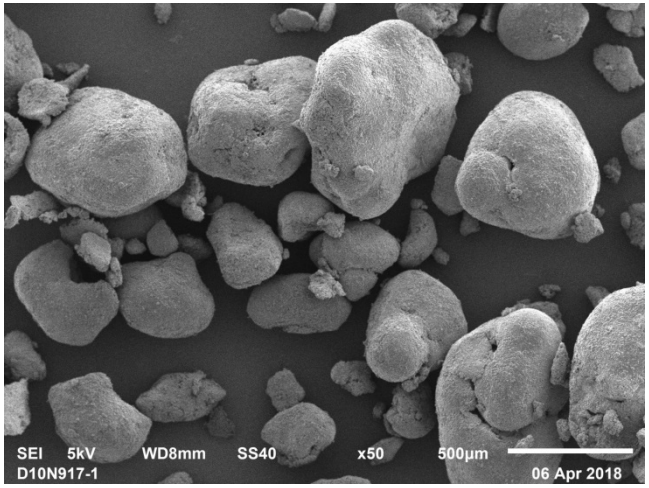
- Building D-10: R&D Pilot Formulation Center
- PBXN-9 FEM (90% FEM)
  - 590 Lbs. produced to date
- LX-14 FEM
  - 536 Lbs. produced to date

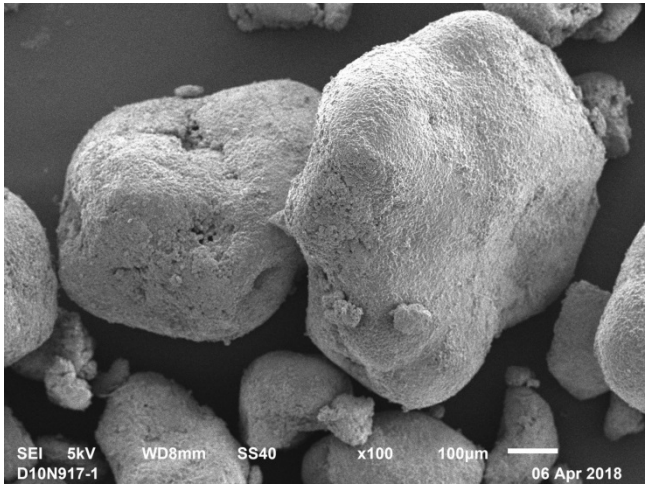


Pilot Plant: PBXN-9 FEM

PBXN-9 with FEM HMX - Analytical Result Summary

Batch/ Notebook #	Lab/Pilot	Batch Size (lbs.)	% FEM HMX	Composition			Bulk Density	Pressed Density	Flowdex	Friction Co-eff	Granulation			Naval Impact		VTS
				HMX %	DOA %	Hytemp %					Pass #6	Pass #8	Pass #40	N-9	RDX Std	
				91.0-93.0	5.0-7.0	1.5-3.0	>0.80 g/cc	>1.73 g/cc		<220	99-100	95-100	0-5	>RDX Std		<0.5
D10N917-1	Pilot	145	90	92.02	5.77	2.21	0.71	1.69	12	208.74	99.8	98.1	45.2	84.14	12.12	0.0304
D10N917-2	Pilot	145	100	91.66	5.83	2.50	0.71	1.677	7	121.77	99.9	99.3	5.1	89.13	12.12	0
D10N917-3	Pilot	300	90	91.78	5.88	2.34	0.67	1.692	9	147.74	99.6	98	9.2	39.81	13.14	0.0247

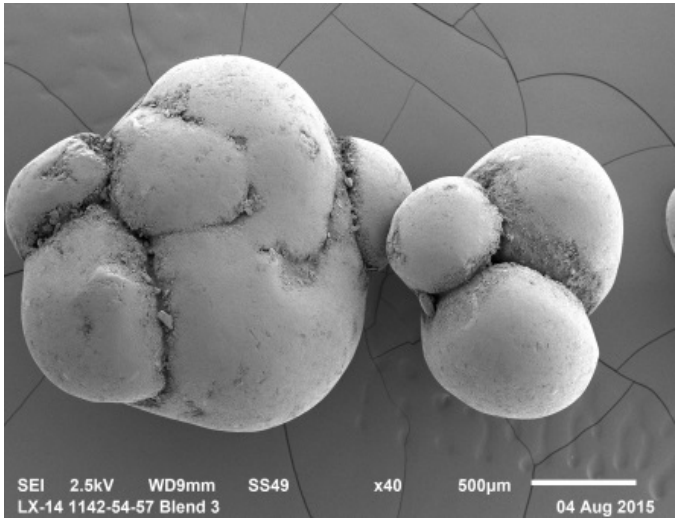


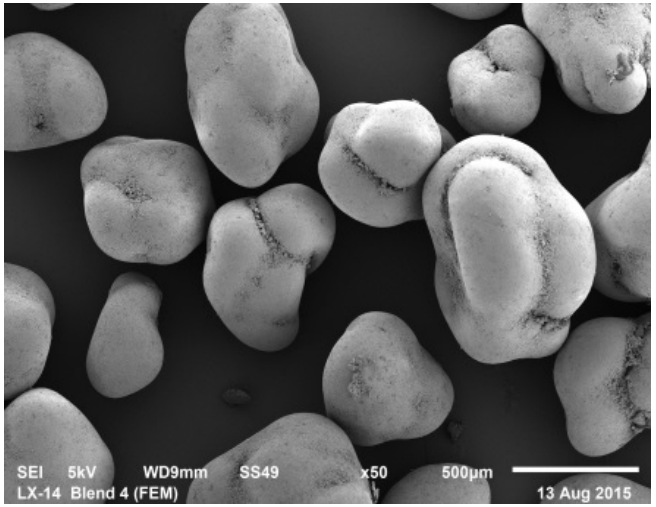


Pilot Plant: LX-14 FEM

LX-14 with FEM HMX - Analytical Result Summary

Batch/ Notebook #	Lab/Pilot	Batch Size	% FEM HMX	Composition		Bulk Density (g/cc)	Volatiles	Granulation				Insolubles		Color
				HMX %	Estane %			Retain 5/16"	Retain #4	Retain #50	Retain #80	USSS #40	USSS #60	
				94.9 - 96.1	*3.9 - 5.1*	*> 0.85 g/cc*	*0.10% Max*	*None*	*1 max*	*95 min*	*98 min*	*0 max.*	*5 max.*	
D10LX14FEM17-1	Pilot	118 lb.	80	96.1	3.90	0.878	0.071	0	0	84.4	13.2	0	0	White
D10LX14FEM17-2	Pilot	300 lb.	80	95.36	4.64	0.85	0.06	0	0	91.8	72	0	0	White
D10LX14FEM17-3	Pilot	118 lb.	80	95.33	4.67	0.877	0	0	0	94	6	0	0	White





Conclusion

- **Reduction of shock sensitivity in PBXN-9 and LX-14**
  - Sensitivity reduction can be tailored with amount of FEM
- PBXN-9 FEM (Containing 90% FEM)
  - Card Gap
    - 186 Cards (Baseline HSAAP Data) / 156 Cards (HSAAP Data)
- LX-14 FEM (Containing 80% FEM)
  - Card Gap
    - 236 Cards (Baseline HSAAP Data) / 166.5 Cards (ARDEC Data)
- No degradation in lethality
- Current IM technology employed
  - No new or exotic cost prohibitive compounds
  - No change in HSAAP manufacturing techniques
- Materials successfully produced to the HSAAP Pilot Plant
- Products currently being assessed in the industrial base LAP infrastructure
- DOD Weapon Platforms
  - Technology could limit expensive full qualification costs for implementation of FEM

Acknowledgements

	•Phil Samuels
BAE SYSTEMS	•R&D Analytical Group •David Price, Jacob Morris, Paul Lucas, Neil Tucker, Erica Lotspeich, Robyn Wilmoth
Nammo Talley	•Andy Davis •Kyle Mychajlonka