Explosives Coating via Advanced Cluster Energetics (ACE™) Fluid Energy Mill (FEM) Technology

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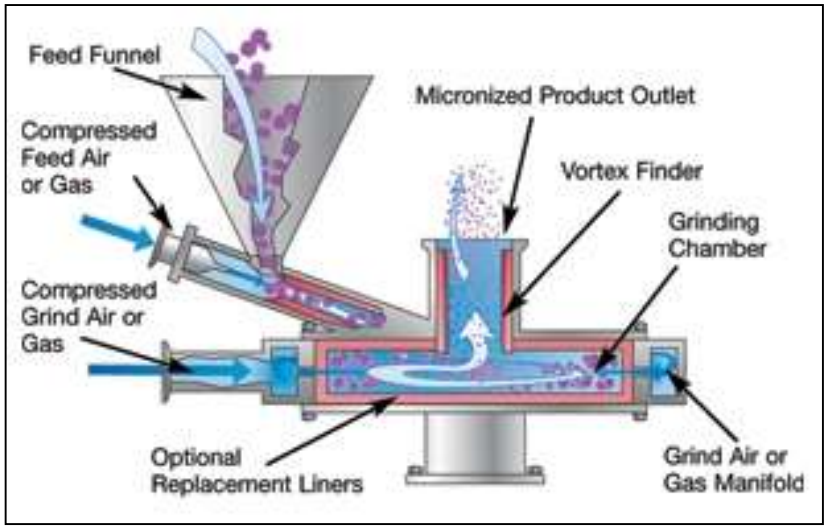
Background

- FEM technology utilizes compressed air to grind particles to less than 10 microns in size
- The ACE-FEM technology has potential to eliminate traditional coating processes
- Coated particles are subjected to particle to particle impact during the mill process where the coating is then re-distributed in-situ to the newly ground product
- Demand for smaller particle size materials to meet IM requirements is increasing

The ACE-FEM Process

- Pre-coated material added to mill system
- Feed air/grind air set to pre-determined position
- Feed rate adjusted for each material
- Product collected
- Analysis of product



Compressor Equipment

- HSAAP Compressor Upgrade
  - Hitachi Model DSP-22AT6I-125 Oil Free Dry Screw Compressor
    - 114 CFM @ 125 psig
    - 240 Gallon epoxy lined reservoir tank
    - Airtek Model TWB200-EB Blower Purge Desiccant Dryer

RDX Feasibility Trials

- Risk mitigation effort
  - Grind RDX Class 1 (uncoated) to determine if 4.0 micron specification can be achieved
  - 50% of trials met spec.
  - 4 non-conformances
    - Missed by less than 2 microns on 90th
  - Feasibility trials produced material that fits spec requirements for:
    - RDX FEM 2.8 micron
    - RDX FEM 4.0 micron

	Malvern Analysis		
Batch #	10th	50th	90th
1099-1205-1	1.393	2.483	4.581
1099-1205-2	1.28	2.532	12.004
1099-1205-13	1.949	3.678	7.074
1099-1205-4	1.745	2.906	4.909
1099-1205-5	1.407	2.596	5.107
1099-1205-14	1.425	2.628	5.261
1099-1205-7	2.106	3.62	6.164
1099-1205-10	3.002	5.827	10.66

RDX Product Milling

- Generate 4.0 micron material for incorporation into MNX-795
  - 1099-1218-1 Produced non-spec compliant material
    - Material build up in exit pipe
  - Repeat of 1099-1218-1
    - Labeled as 1099-1218-2
      - Two separate grinds to confirm free flow mill conditions
  - 1099-1220-1
    - Extended milling yielded spec FEM grade RDX

				Particle Size Distribution			Comp
Milling Date	***Compressor Type***	***Feed Pressure (psi)***	***Grind Pressure (psi)***	**10th**	**50th**	**90th**	***% DOA***
1099-1218-1	HT	High	High	4.427	12.287	35.689	3.88
1099-1218-2	HT	High	High	2.007	4.849	15.307	4.94
1099-1220-1	HT	High	High	2.055	4.725	10.004	5.02

CXM-AF-7 Characterization

- Milled FEM RDX was incorporated with RDX Class 1 w/ DOA
  - Small clumps of FEM still noted after blending
  - Blended sample passed all spec attributes
    - Blended sample by use of twin cone blender
    - Future blending to be conducted with Nauta mixer system for mechanical shear

Batch #	H2O %	Impact (cm)	Impact Std (cm)
Spec	<0.10	-	RDX, Cls 5
1099-130	0.0167	45.71	22.91

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MNX-795 Processing and Test

- MNX-795
  - Wax based melt pour explosive
  - Incorporates CXM-AF-7
    - Lecithin
    - Aluminum Powder
- NOL LSGT Evaluation
  - Conducted at HSAAP Explosives Test Site
  - Standard CXM-AF-7 vs. Milled CXM-AF-7

Material	Card Gap (Cards)	Result	Pressure (kbar)	Density (g/ml)
MNX-795 lit. Value	146.125	GO	40.96	1.634
MNX-795 lit. Value	146.8	No-GO	40.58	1.641
MNX-795 HSAAP	156	GO	35.8	1.615
MNX-795 HSAAP	157	No-GO	35.4	1.611

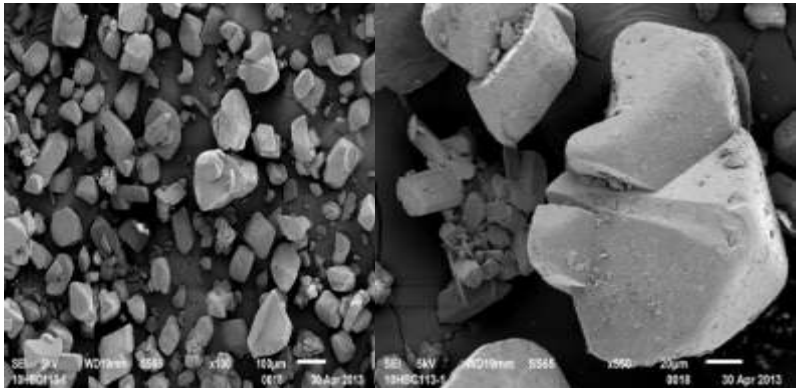
HMX Feasibility Grinds

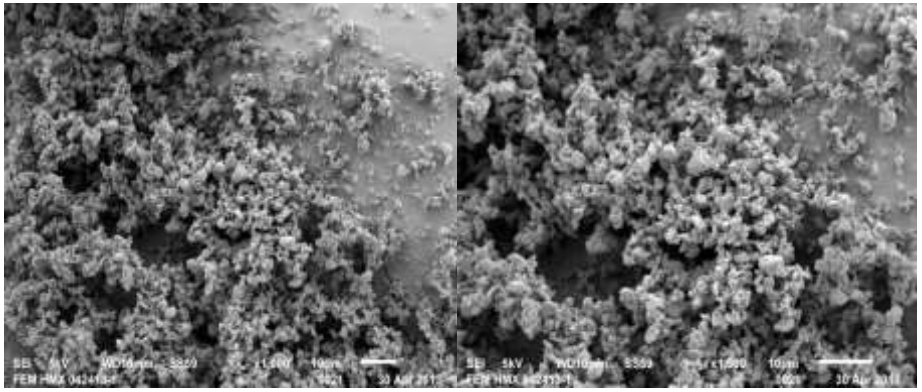
- Product Must Meet HMX Class 5 Specification
- Risk Mitigation Effort
  - Grind HMX Class 1
  - Grind HMX Class 3

HMX Class 5			
Batch Number	10th Percentile (µm)	50th Percentile (µm)	90th Percentile (µm)
6HGF512-1	1.41	3.18	8.98
6HGF512-4	1.8	3.9	9.25
6HGF512-8	1.76	12.79	37.61
6HGF512-13	1.31	3.59	19.58
6HGF512-16	1.92	4.94	26.63
6HGF512-20A	1.46	3.72	13.83
6HGF512-23	1.65	3.55	9.09
6HGF512-30	1.43	3.87	15.32
6HGF512-63	1.47	3.66	12.48
Avg	1.58	4.8	16.97
Stdev	0.21	3.03	9.65

HMX Feasibility Grinds: HMX Class 1

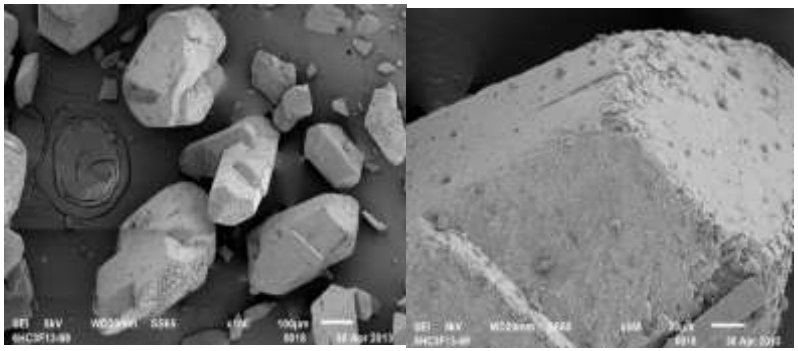
HMX Class 1 (10HBC113-1)			
Batch Number	10th Percentile (µm)	50th Percentile (µm)	90th Percentile (µm)
042413-1	1.655	3.632	14.11
042413-2	1.934	4.197	10.301
042413-3	1.985	4.114	8.144
042413-4	1.695	3.786	11.6
042413-5	1.733	3.787	10.255
042413-6	1.961	3.868	7.432
Avg	1.83	3.90	10.31
Stdev	0.15	0.22	2.41

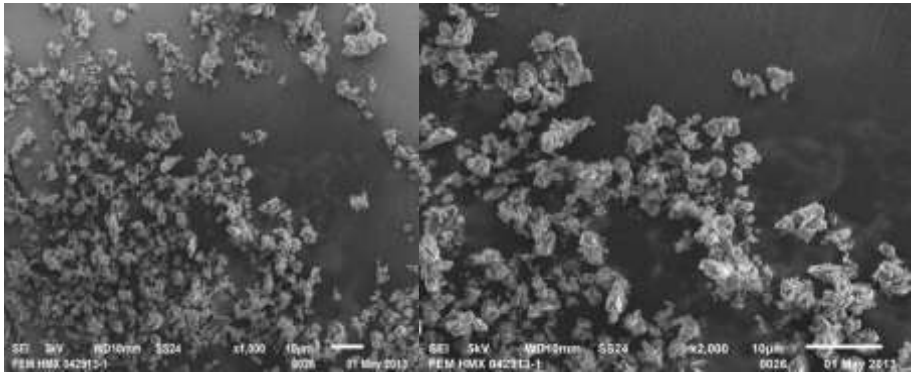




HMX Feasibility Grinds: HMX Class 3

HMX Class 3 (6HC3F13-69)			
Batch Number	10th Percentile (µm)	50th Percentile (µm)	90th Percentile (µm)
042913-1	1.627	3.451	9.745
042913-2	1.972	3.916	8.259
042913-3	2.128	4.136	7.85
042913-4	1.657	3.555	10.198
042913-5	1.674	3.582	11.63
042913-6	1.941	4.054	12.903
Avg	1.83	3.78	10.10
Stdev	0.21	0.29	1.94





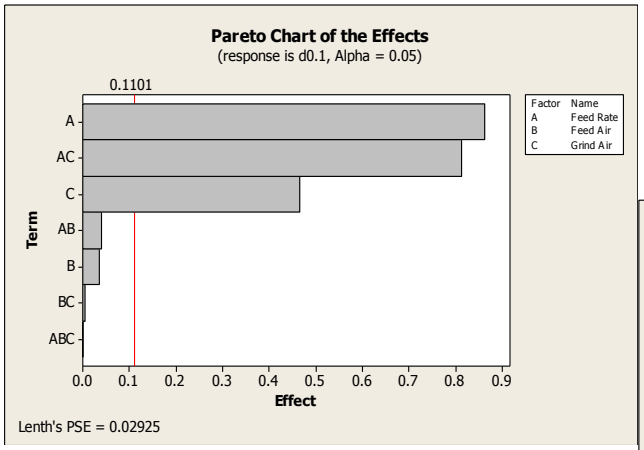
HMX Premix Grind

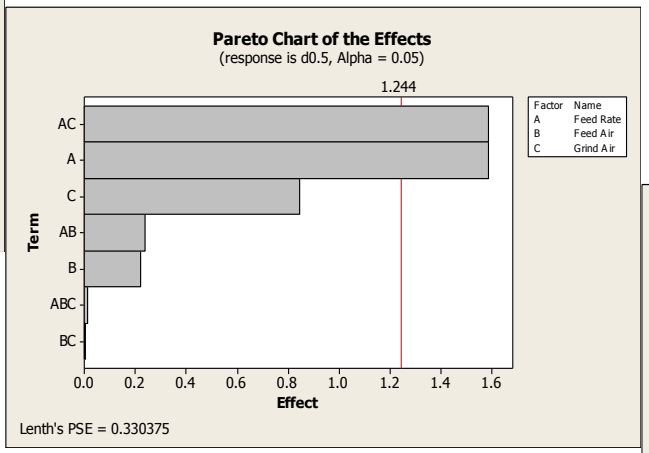
- HMX Class 1 used a feed stock
  - Generated smaller particle distribution span than the Class 3 material
  - Class 1 coated with 3% Isodecyl Perlargonate (IDP) using HSAAP Slurry Technology
- Design of Experiments
  - Determine optimum parameters to mill HMX while retaining IDP coating

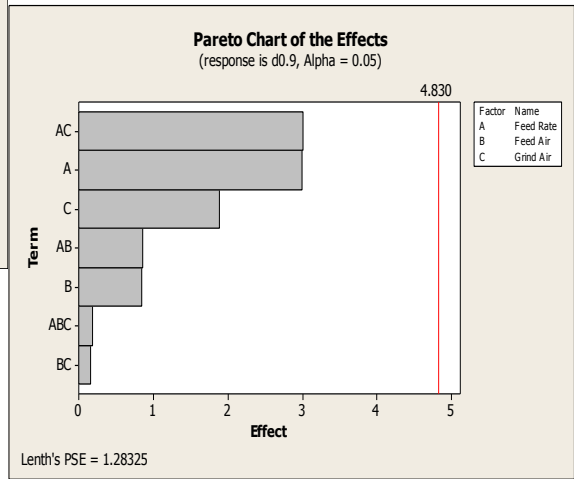
Batch #	StdOrder	RunOrder	CenterPt	Blocks	d0.1	d0.5	d0.9	%IDP	% IDP Loss
090613-001	2	1	1	1	1.715	3.401	6.685	2.84	0.26
090613-002	6	2	1	1	1.364	2.667	5.907	2.77	0.33
090613-003	4	3	1	1	1.637	2.948	5.331	2.65	0.45
090613-004	7	4	1	1	1.282	2.453	4.913	2.79	0.31
090613-005	5	5	1	1	1.273	2.413	4.884	2.68	0.42
090613-007	1	6	1	1	0	0	0	2.65	0.45
090613-008	3	7	1	1	0	0	0	0	0
090613-006	8	8	1	1	1.292	2.199	3.868	0	0

HMX Grind Statistical Analysis

- 1st Pass Effects Model

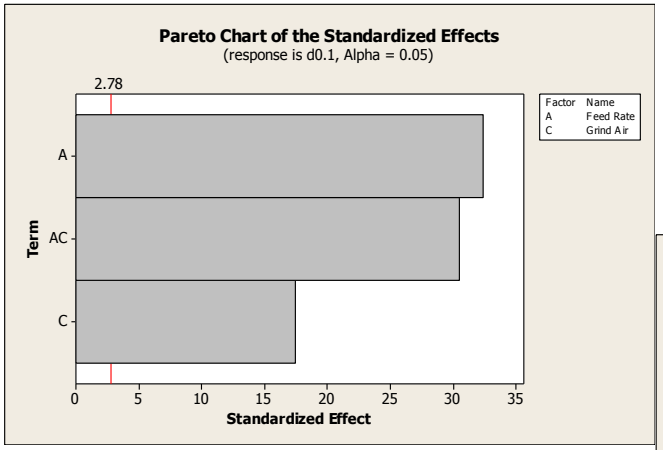


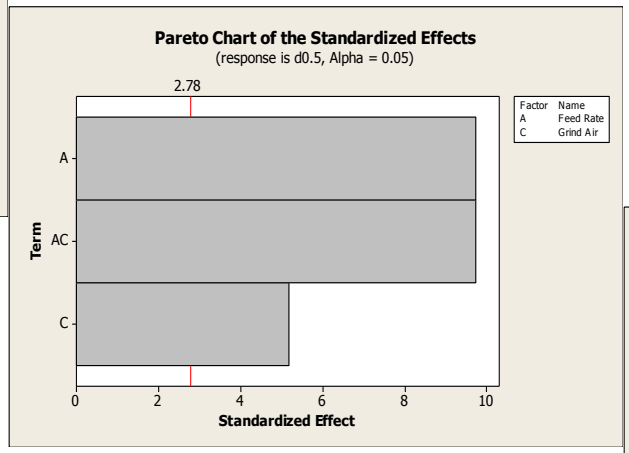


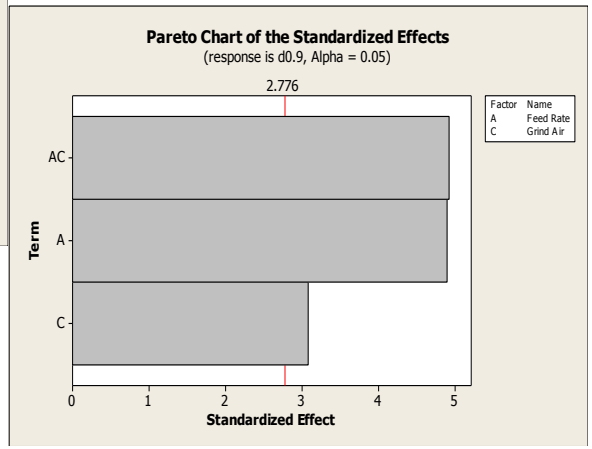


HMX Grind Statistical Analysis

- 2nd Pass Effects Model

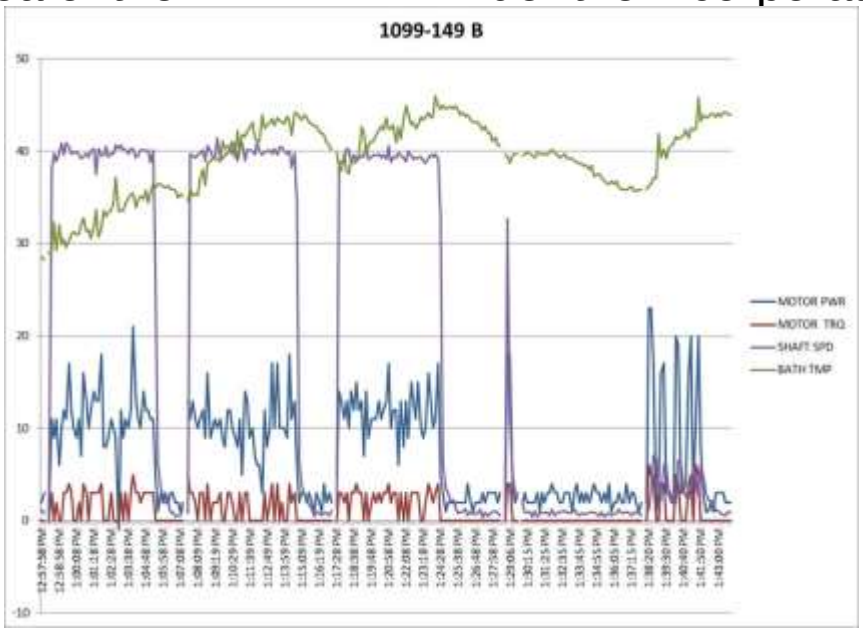






PBX Manufacture and Characterization

- Cast Cure PBXN-114 substituting HMX Class 5 with ACE FEM generated HMX
  - Material was not usable
  - Viscosity of the mixture would not allow for sufficient incorporation of the HMX solids
    - Surface Area of the FEM HMX hinder the incorporation process



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Surface Area Modification: Design of Experiments

- FEM parameters were modified to tailor the product to match HMX Class 5 SA

Batch #	10µ	50µ	90µ	BET Surface Area (m2/g)	% IDP	IDP Diff.
						Avg.
CL 5 HMX Reference						2.79
6HGF12-30	1.539	4.671	20.777	2.3551	N/A	
1131-44A	2.898	6.951	14.858	1.5933	2.00	0.79
1131-44B	1.346	3.359	12.215	3.1607	1.71	1.08
1131-44C	3.024	7.089	14.928	1.5889	1.32	1.47
1131-44D	1.856	4.019	8.546	2.5807	1.48	1.31
1131-44E	3.277	33.514	127.234	0.3456	1.36	1.43
1131-44F	2.547	6.451	14.067	1.9786	2.44	0.35
1131-44G	2.405	5.854	12.759	2.0822	2.24	0.55
1131-44H	3.647	51.144	201.498	0.2548	1.53	1.26
1131-44I	2.735	15.002	48.267	0.8413	1.30	1.49
1131-44J	2.610	7.079	16.955	1.7107	1.37	1.42
1131-44K	1.849	4.037	8.749	2.8636	1.28	1.51
1131-44L	2.031	4.971	13.871	2.3734	2.19	0.60
1131-44M	2.606	6.898	15.000	1.8860	1.54	1.25
1131-44N	2.256	5.828	16.528	2.1818	2.18	0.61
1131-44O	1.903	4.560	10.547	2.4574	1.91	0.88
1131-44P	1.790	4.470	44.822	1.6331	1.24	1.55
1131-44Q	1.873	4.033	8.471	2.5219	1.48	1.31
1131-44R	2.659	17.957	66.045	0.8571	1.14	1.65
1131-44S	1.794	3.844	8.028	2.5018	1.46	1.33
1131-44T	2.982	25.135	101.541	0.3711	1.42	1.37
1131-44U	1.810	3.940	8.447	2.5410	1.42	1.37
1131-44V	3.103	8.640	18.872	1.9006	2.38	0.41
1131-44X	2.721	20.683	63.216	2.0483	1.74	1.05
1131-44Y	3.267	28.111	89.893	0.4124	1.61	1.18
1131-44Z	1.417	3.626	15.324	2.9805	0.79	2.00
1131-44AA	1.957	4.554	10.217	2.8412	2.00	0.79
1131-44AB	1.733	5.375	65.435	1.1131	1.66	1.13
1131-44AC	1.648	3.325	6.710	2.2822	1.53	1.26
1131-44AD	1.803	4.552	56.152	2.4743	0.97	1.82
1131-44AE	1.465	3.327	9.134	3.6142	0.91	1.88
1131-44AF	2.001	4.927	12.756	0.6739	1.95	0.84
1131-44AG	3.540	41.460	179.360	0.4248	1.18	1.61

Conclusion

- ACE FEM technology successfully demonstrated the ability to manufacture CXM-AF-7
- Evaluation of the milled product met all current military specifications
- Large Scale gap Testing showed similar results to literature values
  - The 5kbar variance from literature values most likely due to density variation between the tested and reported charges
- The ACE technology demonstrated the capability to manufacture HMX based premixes
  - Surface area influences more pronounced in the PBXN-114 Formulation
  - Modification of the input premix will allow for incorporation of FEM materials
    - Incorporation and testing of the premix scheduled for Q3 2015