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Next Generation IM Mortar Fill – Optimized PAX-33 Development and Characterization

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Briefing Objectives

- Program Goals
- Background
- Recent Developments
- Material Characterization
- Future Plans
- Summary

Program Goals

- Program began as part of the PAX-21 PIP effort with the initial goals:
  - Replace AP
  - PAX-21 or better performance
  - PAX-21 or better IM
- Initial formulation (OSX-1) achieved those goals
- Goals for further optimization:
  - Improved performance vs. PAX-21
  - Improved IM vs. PAX-21 and OSX-1
  - Applicability across 3 different mortars (60, 81, 120mm)

Background

- OSX-1 formulation developed as part of the PAX-21 PIP effort
  - DNAN
  - NTO
  - RDX
- Objective was to use ingredients manufactured on Production scale at Holston

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Background

- DNAN and NTO - inherently less sensitive than traditional high explosives and melt base ingredients
  - Manufactured in Agile Facility at Holston

Background

OSI FORMULATIONS RELATIVE TO PAX-21 (% $^{w}/_{w}$)

Batch #	DNAN	FEM RDX	HMX	TATB	NTO	Viscosity (sec)	Processability
PAX-21 (ref.)	X	X'	X''	X'''	X''''	≤15	good
1020-148	+2	-9	+5	-	+2	19	good
1033-78	-1	0.5	0	-	+0.5	> I min	*fair*
1033-68 B	-2	9	0	-	-7	> 60	*poor*
1020-142	-3	-6.5	+5	-	+4.5	> 1 min	*poor*
1033-82	-3	-4.6	0	-	+7.64	~20 sec	good
1033-50	-4	-6	+5	-	+5	15.2	good
1033-68 A	-4	-1	0	-	+5	> 60	good
1033-68 C	-4	-8	0	-	+12	15.2	good
OSX-1-01	**-1**	**-6**	**0**	**-**	**+7**	**10.1**	**good**
1033-43 B	+2	-	+5	+15	+14	4	good
1033-32	+2	-	+10	+15	+9	15-19	good
1029-124	0	-	+5	+20	+11	n/a	*poor*
1033-47	-1	-	+5	+16	+16	11.4	good
OSX-3	**-1**	**-**	**+5**	**+16**	**+16**	**~20 sec**	**good**
1029-142	+6	-	-	+14	+16	10.4	good

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Background

OSX-1 Formulation Testing

Formulation	Navy Impact (cm)	DSC Melting Point (°C)	DSC Decomposition Temperature (°C)	Velocity of Detonation (% PAX-21)	LSGT Card Gap (# cards)
PAX-21	27-30 (typical)	89 (typical)	193 (typical)	100	155 ± 5
OSX-1	78	88	207	113	144

Background

120mm Smooth Bore Mortar - Adhesion

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Recent Developments

- OSX-1 assigned the designation PAX-33 by ARDEC
- Additional development program funded to optimize PAX-33 formulation for mortar application
  - Optimization of formulation for performance and processability
  - Determine effects of Methyl Nitroaniline (MNA) on formulation
  - Analytical methods development for product and ingredients
- Modified ratios and concentration of ingredients in PAX-33
  - Target was reduced sensitivity and improved performance

Recent Development

- Several iterations of formulations were examined
- OSX-7 formulation identified as the candidate to optimize
- Ingredient ratios modified
  - DNAN
  - NTO
  - RDX

Material	TMD (g/cc)	VOD (% Comp B)	VOD (% TNT)	LSGT (Cards)	Reference	Scale of Manufacture to Date	DSC MP / Exotherm Onset (°C)	Efflux Viscosity (sec.) @ 96°C
TNT	1.654	84	100	133	MSIAC	Production (1200 - 1500 Lb scale)	-	-
Comp B	1.76329	100	120	207	LLNL / NOL		80 / 215	-
PAX-21	1.72857	83	99	161	ARDEC		89 / 193	4.8 - 8.6
PAX-33	1.73614	89	106	144	UTEC / ARDEC		88 / 207	8.7
PAX-34	1.76098	83	99	104	ARDEC		92 / 231	8.5
OSX-7 (PAX-33, II)	1.728	98	113	118	OSI		89 / 213	6.6
OSX-8	1.76	96	113	110	OSI		93 / 231	5.3
OSX-9	1.75	97	108	106	OSI		88 / 199	10.5

Recent Developments

- OSX-7
  - Large scale manufacture in Holston production equipment (1200 lb. batch)
  - Material supplied to PM CAS for loading into mortars

Recent Developments

- MNA introduced as an ingredient in PAX-21 to lower the melting point of the formulation
- Effect of MNA concentration on melting point and exotherm onset of DNAN was explored
  - Samples containing 0.0%, 0.1%, 0.3%, 0.5%, 1.0% and 5.0% MNA by weight were analyzed by DSC
  - MNA added as dry powder in one set of samples and melted together with DNAN in the other set of samples
- Effect of MNA concentration on melting point and exotherm onset of PAX-33 was explored
  - Samples containing 0.0% and 0.25% (typical concentration in PAX-21) MNA by weight were analyzed by DSC
  - MNA added by melting together with the PAX-33

Recent Developments

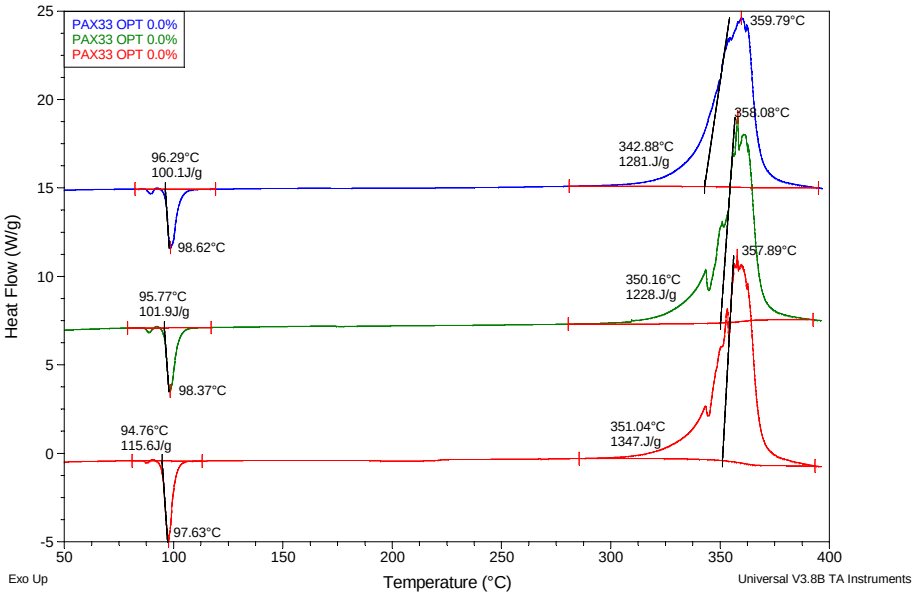
- The addition of MNA to DNAN did not have a significant effect on the melting point or exotherm at concentrations less than 5.0%
- At a concentration of 5.0%, the MNA lowered both the melting point and the exotherm of DNAN significantly

Thermal effect analysis– MNA mixed with MOLTEN DNAN

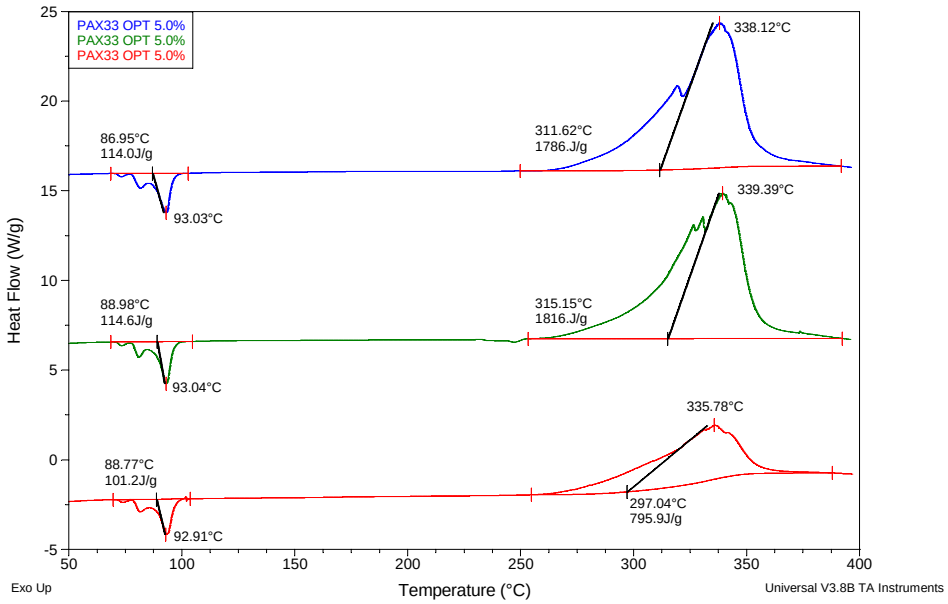
Sample ID	%MNA	Melting Point (°C) (Avg. of 3)	Exotherm (°C) (Avg. of 3)	Standard Deviation
PAX 33 OPT 0.0%	0.0	98.21	358.59	1.046
PAX 33 OPT 0.1%	0.1	96.45	357.7	1.195
PAX 33 OPT 0.3%	0.3	96.61	356.86	1.828
PAX 33 OPT 0.5%	0.5	97.12	354.37	2.084
PAX 33 OPT 1.0%	1.0	97.05	351.81	0.837
PAX 33 OPT 5.0%	5.0	92.99	337.76	1.831

Recent Developments

DNAN Melted with 0.0% MNA

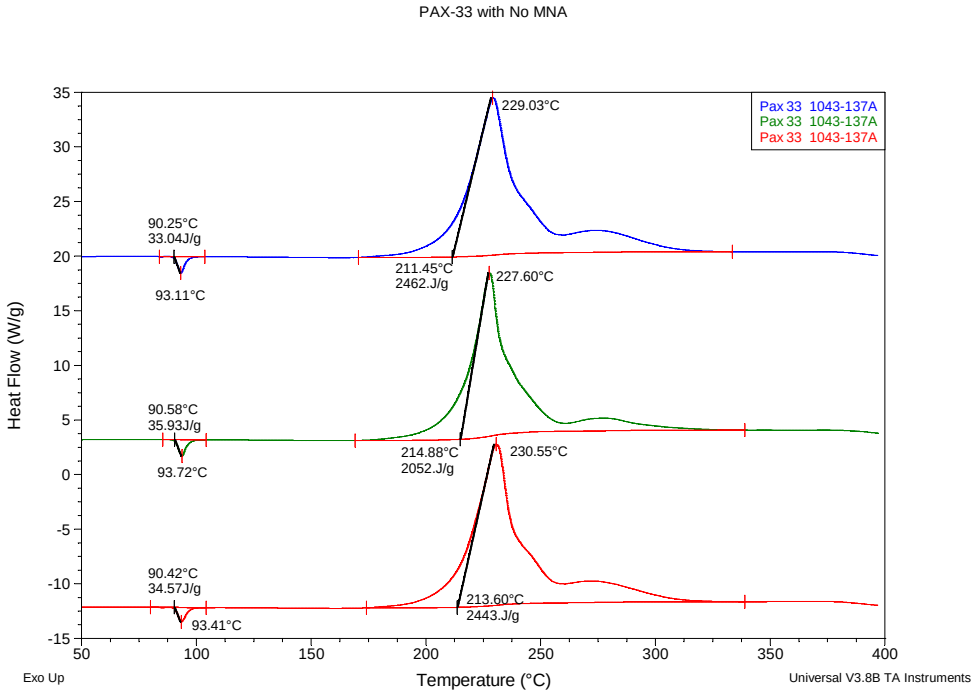


DNAN Melted with 5.0% MNA



Recent Developments

- Results of MNA study
  - The addition of MNA at a level of 0.25% to PAX-33 lowered the melting point by 1.6% over PAX-33 with no MNA
  - The melting point of PAX-33 with no MNA was 4 - 5°C lower than DNAN
  - The addition of an organic compound, whether MNA or NTO or RDX, lowers the melting point



Thermal effect analysis– MNA mixed in PAX-33 formulation

Sample ID	%MNA	Melting Point (°C) (Avg. of 3)	Exotherm (°C) (Avg. of 3)	Standard Deviation
PAX 33 1043-137A	0	90.42	213.31	1.733
PAX 33 1043-137B	0.25	88.83	207.8	0.884

Future Plans

- OSX-7 (PAX-33 Type II) - candidate for PM CAS IM Mortar Program
- Material to be tested in 120mm Mortar
- Additional testing on 60mm and 81mm mortar planned
- OSX-7 provided basis for further formulation development using DNAN and NTO (OSX-8 and OSX-9)

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Summary

- Optimized formulation developed as PAX-33 Type II (OSX-7)
  - Low-cost replacement melt-pour fill for mortars with Comp B performance
  - Reduced shock sensitivity vs. Comp B and PAX-21
  - Price around $14 - $16 / lb. for large quantities
  - Ingredients readily available and manufactured at Holston
  - Viable candidate for common fill across all mortar sizes

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