



2010 IM/EM Technology Symposium
October 11-14, 2010

Additional Properties Studies of DNAN Based Melt-Pour Explosive Formulations

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Introduction and Background

- Insensitive High Explosive (IHE) formulations used in Insensitive Munitions (IM) were mainly cast-cured or pressed formulations until recently.
- New developments in melt-pour IHE and work that showed that they could also have good IM properties revived the interest for the type of explosive processing.
- Expertise with melt-pour explosive was acquired with TNT-based formulations at GD-OTS Canada for more than 60 years .
- We have acquired experience with DNAN based formulations for the past ten years first with ATK Thiokol developed PAX-21, PAX-25 and then with BAE OSI developed PAX-34 and PAX-33.
- The objective of this presentation is to present the tests performed on two dinitroanisole (DNAN) based formulations (OSX-7 now known as IMX-104 and OSX-8 now known as PAX-48) and their results obtained to complete results presented at the Tucson symposium.

Overview of Formulations Tested

- **IMX-104 (OSX-7): DNAN, NTO, RDX**
- **PAX-48 (OSX-8): DNAN, NTO, HMX**
- **Reference formulation:**
  - Composition B: 59.5% RDX, 39.5% TNT, 1.0% wax
- **Components:**
  - DNAN: Dinitroanisole
  - NTO: 3-nitro-1,2,3-triazol-5-one
  - HMX: Octogen
  - RDX: Hexogen

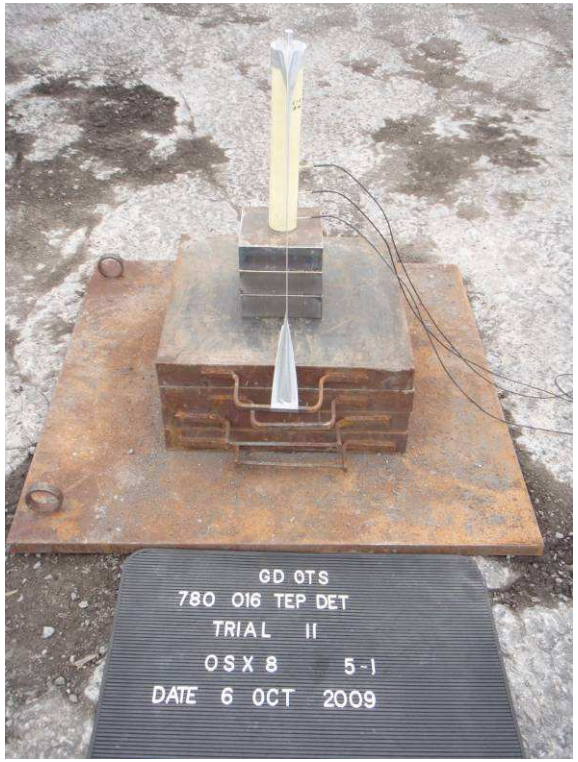
Previous work

- **Processing variables characterisation**
  - Viscosity and solid particles settling.
  - Cooling behaviour in straight cylinder
- **Filling of both 105mm M1 artillery and 81mm C70A2 mortar projectiles.**
- **Mechanical and physical properties**
- **VCCT with intermediate heating rate (25℃/hr or 45° F/hr)**

Detonation performances

- Detonation velocities and pressures obtained from computer calculations performed with LLNL Cheetah 5.0 thermochemical code following validation of the code with other explosives of the same type.

- Experimental measurements of detonation velocity and plate dents using a set-up similar to the one used by DRDC Valcartier
  - Tested sample: straight cylindrical sample (25.5 cm (10") long x 5.1 cm (2") diameter
  - Booster: Composition A5 pellet
  - Detonator: Dyno Nobel electric Super SP
  - Measurement of detonation velocity (VOD) from recording on three (3) ionization probes at 1.0 cm (0.4"), 6.1 cm (2.4") and 11.2 cm at (4.4") from bottom of sample; 5mm (0.2") from side wall
  - Dents measured on AISI 1018 plate (15 cm (6") x 15 cm (6") x 5.1 cm (2") thick).



Detonation performances

- BKW equation of state and BKWC product library provided the best results for melt-pour explosives, including the older DNAN formulations PAX-21 and PAX-25.
- Properties relative to composition B

Properties \ Formulations	IMX-104 (OSX-7)	PAX-48 (OSX-8)
Detonation velocity (Computed)	92.4%	91.2%
Detonation velocity (Experimental)	94.4%	92.6%
Detonation pressure (Computed)	82.8%	79.5%
Detonation pressure (Experimental)	81.5%	82.8%
Gamma CJ (Computed)	102.0%	101.9%
Gurney coefficient $(2E)^{1/2}$ (Computed)	90%	88%

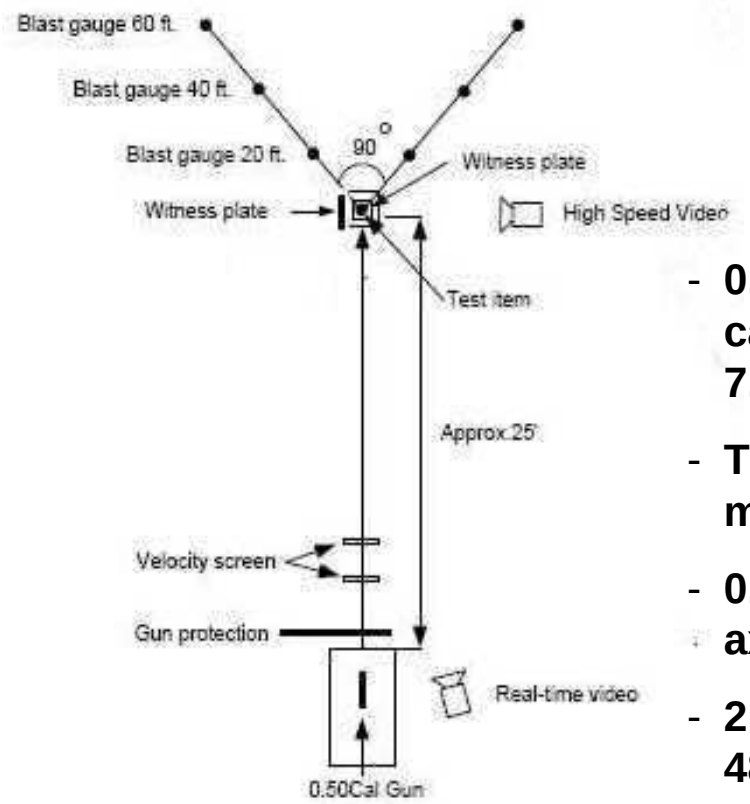
Detonation performances

Comments:

- The experimental detonation velocities and pressures relative to composition B are within 3% of the values obtained with Cheetah 5.0 thermochemical code so the simulation results can be considered satisfactory.
- The computed Gurney coefficients of these formulations are about 90% of the composition B value. This is lower than what is normally indicated by other scientists based on fragmentation tests so it would be of interest to conduct cylinder tests to confirm them.

Bullet Impact Test

➢ Test Set-up



- **0.5 cal 36" Mann barrel mounted on a mobile carriage fitted with solenoid for remote firing set at 7.6 m (25') from the test item**
- **Test on bare filled 105mm M1 with inert PRF mounted on a table at 1.5m from the ground**
- **0.5 cal APM2 cartridges fired at the longitudinal axis, 12.5cm (5") from the top of the driving band.**
- **2 tests each on composition B, IMX-104 and PAX-48**
- **6 pencil type blast gauges in two rows of three at 6.1m (20'), 12.2m (40'), 18.3m (60') from test item**

Bullet Impact Test

Results

- Composition B
- Reaction Type I or II
- Pressure records close to static detonation

Bullet Impact Test

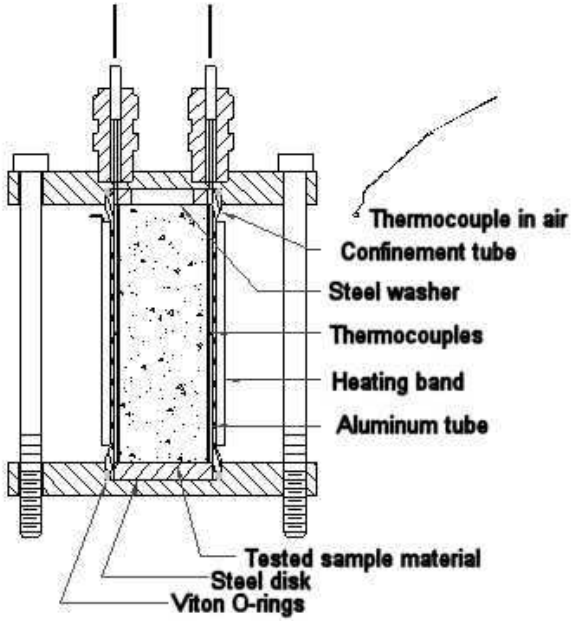
- **Results**
  - **IMX-104 (OSX-7)**
  - **Reaction level V**
  - **Limited reaction visible (high speed video)**

Bullet Impact Test

- **Results**
  - **PAX-48 (OSX-8)**
  - **Reaction level V**
  - **Limited reaction visible (high speed video)**

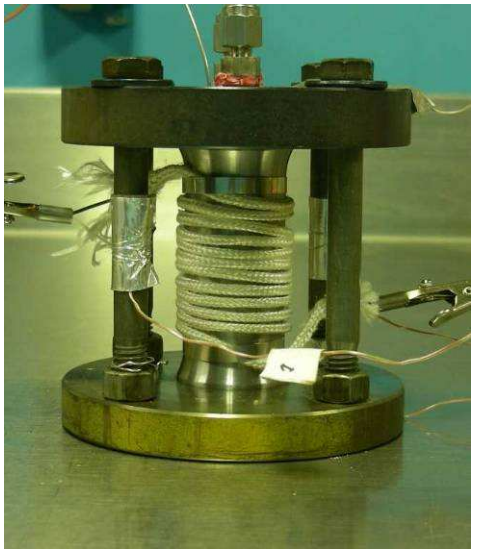
Variable Confinement Cook-off Test

- **Test set-up**



Sketch of general set-up

Slow/intermediate VCCT set-up



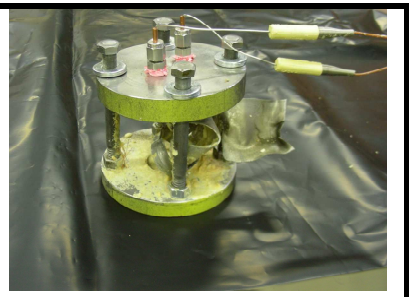
Fast VCCT set-up

Variable confinement cook-off tests

Results

- **Intermediate heating rate (25℃/hr or 45℉/hr)**

Formulation	0.39mm (0.0155") confinement		1.14mm (0.045") confinement	
	Reaction T°	Reaction type	Reaction T°	Reaction type
IMX-104 (OSX-7)	182℃ (360℉)	V	179℃ (354℉)	V
PAX-48 (OSX-8)	189℃ (372℉)	V	190℃ (374℉)	V
Composition B	182℃ (360℉)	II - III	183℃ (361℉)	I



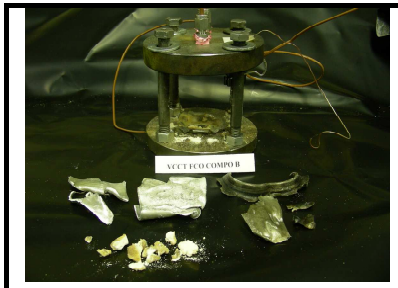
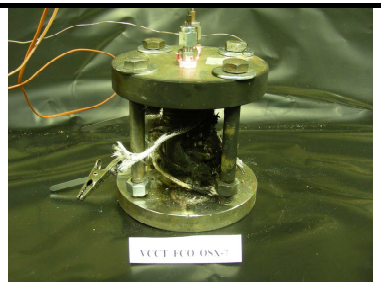
0.39 mm (0.0155")	1.14mm (0.045")	0.39 mm (0.0155")	1.14mm (0.045")
Composition B		PAX-48 (OSX-8)	

Variable confinement cook-off tests

Results

- **Fast heating rate (Curve matching STANAG 4491)**

Formulation	0.39mm (0.0155") confinement		1.14mm (0.045") confinement	
	Reaction T°	Reaction type	Reaction T°	Reaction type
IMX-104 (OSX-7)	245℃ (473℉)	V		
PAX-48 (OSX-8)				
Composition B	218-242℃ (424 - 468℉)	III		

			
0.39 mm (0.0155")	1.14mm (0.045")	0.39 mm (0.0155")	1.14mm (0.045")
Composition B		IMX-104 (OSX-7)	

Summary

- Two IM DNAN based melt-pour formulations, IMX-104 (OSX-7) and PAX-48 (OSX-8), were further studied in GD-OTS Canada in continuation of previous work.
- The experimental values of detonation velocities and pressures for IMX-104 and PAX-48 are close to the values obtained with Cheetah 5.0. Both formulations gave similar results with IMX-104 being slightly better.
- The detonation velocities of IMX-104 and PAX-48 are about 90% of the composition B values and the detonation pressures are about 80% of the composition B values. The Gurney coefficient of these formulations obtained from computations is about 90% of the composition B value.
- Bullet impact tests conducted with 0.5 cal APM2 bullet on bare 105mm M1 projectiles led to Type V reactions for both IMX-104 and PAX-48 compared to Type I for the composition B filled projectile used as the baseline.

Summary

- Intermediate heating rate results (25℃/hr (45℉/hr)) f rom variable confinement cook-off test (VCCT) performed with 0.39mm (0.0155") and 1.14mm (0.045") confinements produced respectively an explosion/partial detonation and a detonation for composition B. A burning reaction was obtained for both IMX-104 and PAX-48 at both confinement thicknesses.
- Fast heating rate VCCT (heating curve similar to STANAG 4491) results performed with 0.39mm (0.0155") confinement produced respectively an explosion for composition B and a burning reaction for both IMX-104.

Future work

- **Additional characterization studies: physical properties during ageing, Cylinder tests, LSGT, additional VCCT at other confinement thicknesses, additional IM tests on 105mm M1 projectiles**
- **Tests on other DNAN based formulations like OSX-12**