Studies on OSX-12 formulation, an aluminized DNAN based melt-pour explosive

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Outline

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- Formulations studied
- Material characterization
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- Acknowledgements

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, IMX-104 (OSX-7), PAX-48 (OSX-8).
- The objective of this presentation is to present the tests performed on one aluminized (DNAN) based formulation labeled OSX-12 including review of results on detonation tests of IMX-104.

Formulations Studied

- OSX-12: DNAN, NTO, RDX, Aluminum
- IMX-104 (OSX-7): DNAN, NTO, RDX
- 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
  - RDX: Hexogen

Material Characterization
Viscosity – Sedimentation - Cooling behavior

- Viscosity and particle size distribution of the solids are important characteristics for melt-pour formulations
- Viscosity affect filling quality in terms of cavities or porosity
- High viscosity may cause difficult operation such as mixing and pumping.
- Low viscosity may enhance solid particle settling
- GD-OTS Canada has developed a series of characterization tests to evaluate the formulation viscosity and the solid particles sedimentation tendency

Viscosity and Sedimentation Testing

- The test is performed using a double jacket heated pot containing 1.5 kg of material with a Brookfield viscometer equipped with a “A” T-shaped spindle rotating at 20 RPM.
- Viscosity measurements taken after 0, 7.5 and 15 minutes.
- In between measurements, the material is allowed to settle freely, without being agitated.
- The test temperature is maintained throughout the test duration.

Viscosity and Sedimentation Testing

- Viscosity measurements
  - OSX-12 and IMX-104 initial viscosity comparable
  - OSX-12 viscosity after 15 minutes resting is very high
  - Significant sedimentation with OSX-12 without agitation

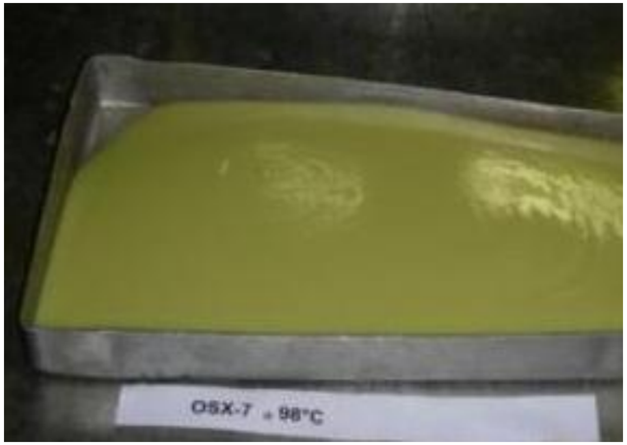
Formulation	OSX-12	IMX-104	Composition B
Test Temperature (°C)	96	96	93
Initial Viscosity (cP)	2640	2060	700-1000
Viscosity after 7.5 min (cP)	3760	2012	1000-1400
Viscosity after 15 min (cP)	9100	2780	2000-2400

Viscosity and Sedimentation Testing

- The viscosity test is immediately followed by the sedimentation test.
- The material in the heated test pot from the viscosity test is poured onto a pan and observations are made on
  - The way the material flows
  - The amount of material remaining in the test pot
  - The way the material places itself on the pan
- Significant material deposition on the bottom of test pot
- Visible shiny greenish layer of supernatant at the top of the explosive

Viscosity and Sedimentation Testing

Pouring test pictures – OSX-12



Pouring test pictures – IMX-104

Viscosity and Sedimentation Testing

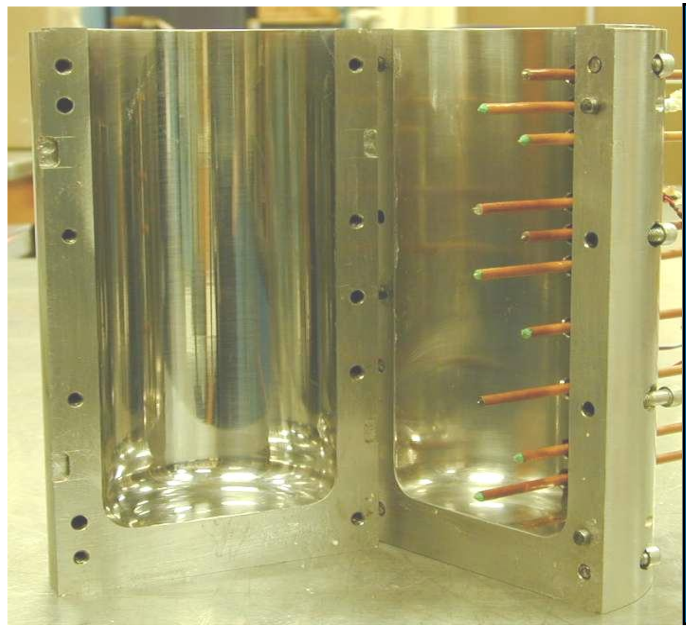
- Chemical characterization
  - Deposit composed of NTO and Al
  - Supernatant is concentrated with DNAN

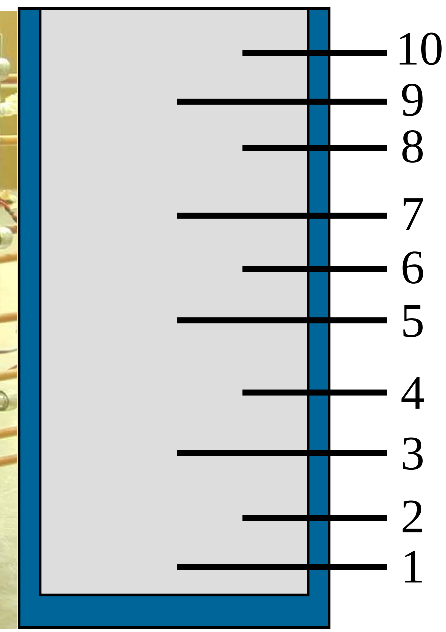
Percentage relative to pristine material	% Al	% NTO	% RDX	% DNAN
Sediment	111%	115%	102%	80%
Supernatant	0.72%	0.84%	53%	294%

Cooling behavior and chemical characterization

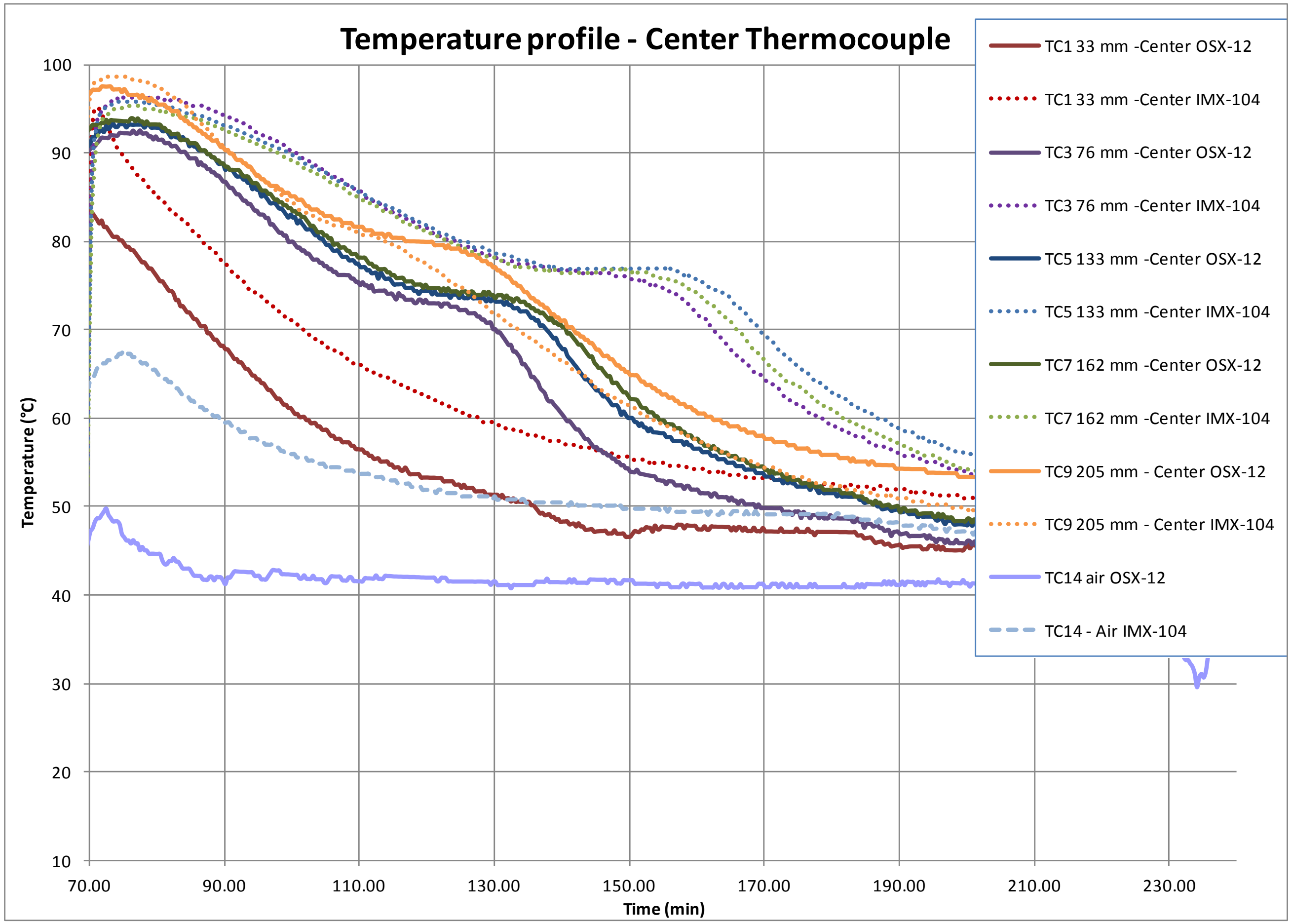
- With melt-poured formulations, controlled solidification is required to prevent formation of defects in the cast.
- GD-OTS Canada has developed a comparative test involving an instrumented heated cylinder.

- The explosive is poured and cooled under stable conditions.
- Temperature cooling curves are recorded and compared.
- Chemical characterization (HPLC) is performed on 15 samples coming from slabs of 1 inch each.





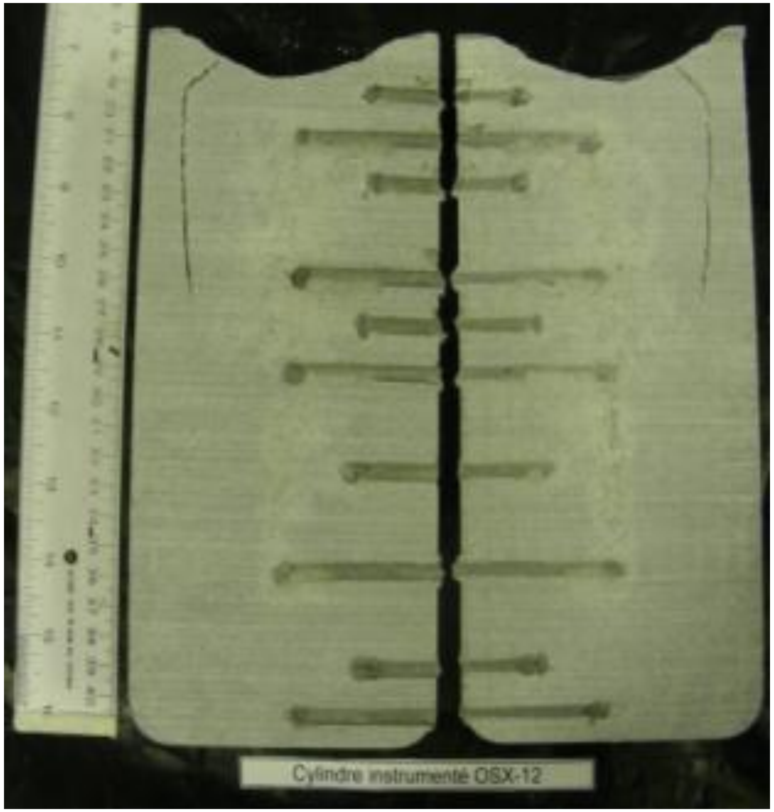
Cooling Behavior



OSX-12 cools and solidifies faster than IMX-104 and much faster than Comp B

Total solidification time: Comp B - 160min; IMX-104 – 90 min; OSX-12 – 70min

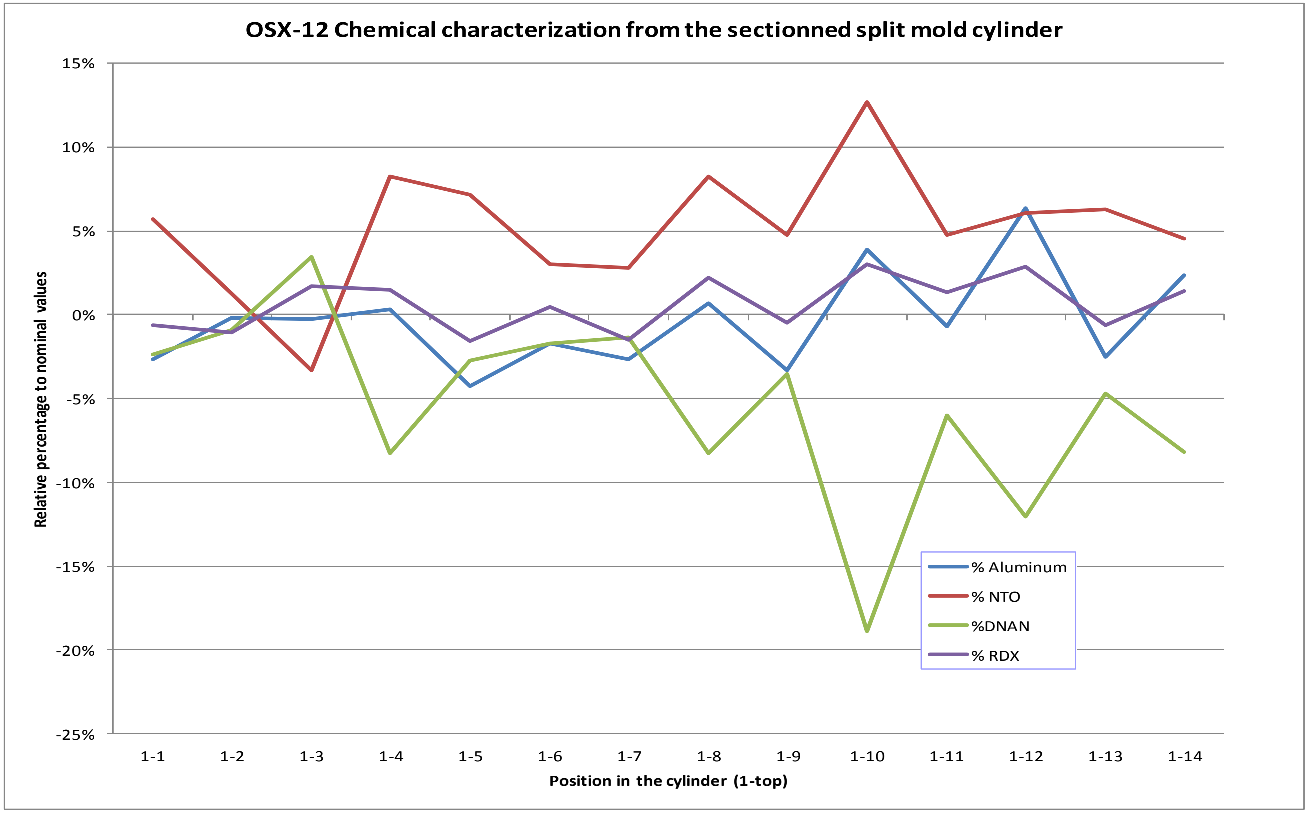
Cooling Behavior



Sectioned Charge from the instrumented cylinder – Left OSX-12; right IMX-104
OSX-12: large cylindrical crack in the external diameter of the charge
OSX-12: Not well defined contraction zone at the center
OSX-12: Lower density material area in the center from the top to a very deep region inside the cylinder

Chemical Characterization

- ➢ Relative percentages of components from samples taken in the cylinder
- ➢ Increase of the solids components towards the bottom – mainly for NTO
- ➢ At position 10 (5 inches from the bottom), 20% less DNAN and solids concentration because of fast solidification at the bottom of the cylinder.



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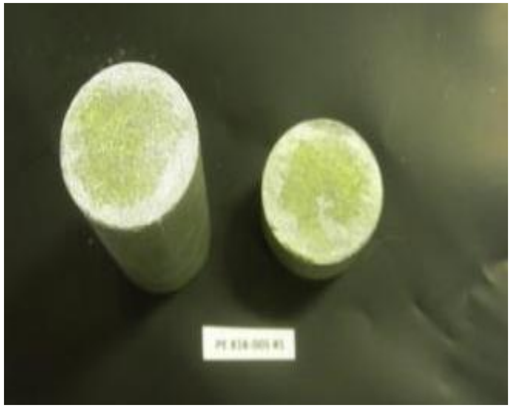
Cylinders and Projectiles Casting

- Cylindrical samples for VCCT, LSGT, VOD/dent tests were cast
  - Diameters from 1 to 3 inches and length from 2.75 to 10 inches
  - Some equipment modification were necessary to adapt to the OSX-12 characteristics
- 105 mm HE M1 shell body were loaded using standard process conditions.
  - A shell body instrumented with 6 thermocouples was included to record the cooling temperature profile
  - Radiographic inspection and shell sectioning was performed

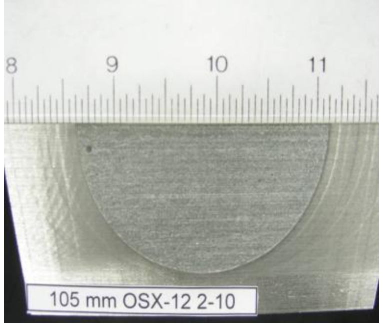
Cylinders and Projectiles Casting

- Fast cooling of upper material caused the trapping of the separated DNAN inside the cylinders.
- In order to avoid this effect, the cooling process in the upper area had to be delayed with longer risers and less conductive material.



Cylinders and Projectiles Casting

- Temperature curves indicate very fast cooling for complete solidification (25 minutes shorter than IMX-104 which is already 60 minutes shorter than composition B)
- Good filling quality (adhesion, wall separation, cavities, porosity and cracks)
- The Meissner process using the probes and coils allows the DNAN separation phase to come at the top of the risers
- A chemical characterization performed on slabs inside the projectile show very little differences
- The fast cooling process overcomes the sedimentation and provides a uniform profile inside the projectile



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Detonation performances

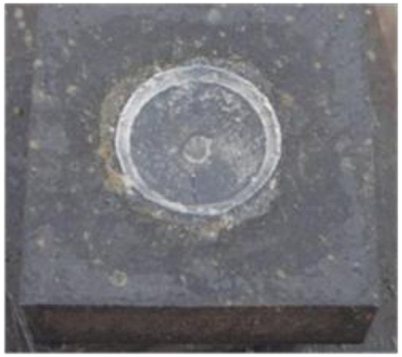
- Detonation velocities and pressures obtained from computer calculations performed with LLNL Cheetah 5.0 thermochemical code following validation of the code with other explosives of the same type.
- Experimental measurements of detonation velocity and plate dents using a set-up similar to the one used by DRDC Valcartier
  - Tested sample: straight cylindrical sample (25.5 cm (10") long x 7.6 cm (3") diameter
  - Booster: Composition A5 pellet
  - Detonator: Number 8 detonator
  - 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 tested on AISI 1018 steel plate (15 cm (6”) x 15 cm (6”) x 5.1 cm (2”) thick)
  - Dents measured on 44W grade steel plate (20 cm (8") x 20 cm (8") x 7.6 cm (3") thick).

Detonation performances

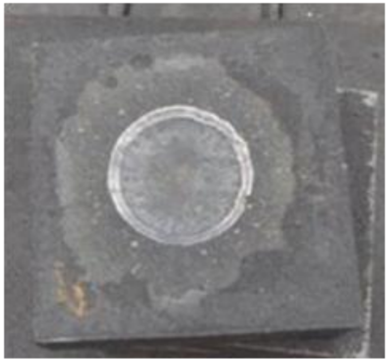
➢ Plate dent results

- **5.1 cm (2in) thick AISI 1018 steel witness plates (Composition B)**

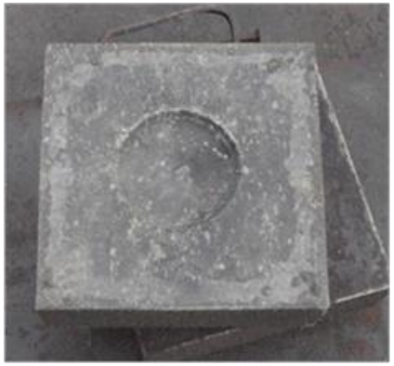
- **7.6 cm (3in) thick 44W grade witness plates (Composition B)**



Composition B



IMX-104



OSX-12

Detonation performances

- BKW equation of state and BKWC product library provided the best results for melt-pour explosives, including aluminized explosives.
- Individual properties values relative to composition B
- Experimental results obtained from the cylinders tested upside down produced were very similar than the others samples of a given type indicating that the sedimentation effect on this property was minimal.

Properties \ Formulations	IMX-104 (OSX-7)	IMX-104 (OSX-7)	OSX-12
Sample diameter	5.1 cm	7.6 cm	7.6 cm
Density [g/cm^3]	1.74	1.74	1.83
Detonation velocity (computed)	95.7%	95.7%	93.2%
Detonation velocity (experimental)	94.4%	94.5%	90.9%
Detonation pressure (computed)	88.4%	88.4%	80.8%
Detonation pressure (experimental)	81.5%	95.8%	92.1%
Gamma CJ (computed)	102.0%	102.0%	97.3%
Gurney coefficient ($\sqrt{2E}$) (computed)	90.0%	90.0%	85.7%

Summary

- The OSX-12 formulation has a higher viscosity, a higher sedimentation tendency and a faster cooling behavior than the IMX-104.
- By adjusting GD-OTS Canada process parameters, it was possible to obtain good filling quality of 105mm M1 Shell body.
- Tests performed with 5.1 and 7.6 cm diameter cylinder sample of IMX-104 produced similar values for detonation velocities (about 94% of composition B)
- The detonation pressure values are very different however with the smaller size sample yielding 81.5% of the composition B value while the larger gave 95.8%. (Steel witness plates used for 7.6mm sample tests made of 44W grade rather than AISI 1018 used with 5.1 cm samples.
- The experimental values of detonation velocities and pressures 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 OSX-12 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.

Future work

- Physical properties during ageing, large scale gap tests (LSGT), insensitive munitions tests (small and full scale) as well as filling of other types of projectiles are planned to further continue the characterization of the OSX-12
- Studies on the steel witness plates used to conduct the dent tests will also be required to confirm the detonation pressure test results
- Cylinder tests may also be good to validate the Gurney coefficient

Acknowledgements

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