Processing Studies of DNAN Based Melt-Pour Explosive Formulations

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Pierre Pelletier, Isabelle Laroche, Daniel Lavigne, Frank Cantin: GD-OTS Canada
Patrick Brousseau: DRDC-Valcartier
Virgil Fung: BAE Systems OSI

Introduction and Background

- Until recently, Insensitive High Explosive (IHE) formulations used in Insensitive Munitions (IM) were mainly cast-cured or pressed formulations.
- New developments in melt-poured IHE and work that showed that they could also have good IM properties revived the interest for the type of explosive processing.
- GD-OTS Canada (formerly SNC TEC) has more than 60 years experience with TNT-based formulations, as well as some experience with PAX-21, PAX-25 and PAX-34 DNAN-based formulations.
- The objective of this presentation is to present the tests performed on two dinitroanisole (DNAN) based formulations (OSX-7 and OSX-8) as well as the results obtained.

Formulations Tested

- **OSX-7: DNAN, NTO, RDX**
- **OSX-8: DNAN, NTO, HMX**
- **Reference formulations:**
  - Composition B: 59.5% RDX, 39.5% TNT, 1.0% wax
  - PAX-34: DNAN, NTO, TATB, HMX
- **Components:**
  - DNAN: Dinitroanisole
  - NTO: 3-nitro-1,2,3-triazol-5-one
  - HMX: Octogen
  - RDX: Hexogen
  - TATB: 1,3,5-triamino-2,4,6-trinitro benzene

Viscosity and Sedimentation Testing

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- Viscosity and particle size distribution of the solids are important characteristics for melt-pour formulations.
- A high viscosity can impair mixing and pumping operations and can lead to more air entrapment during loading.
- A low viscosity can also affect air entrapment and enhances solid particles settling in the equipment and in the loaded shell bodies.
- GD-OTS Canada series of characterization tests are used to evaluate the formulation viscosity and the tendency of its solid particles to settle.

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

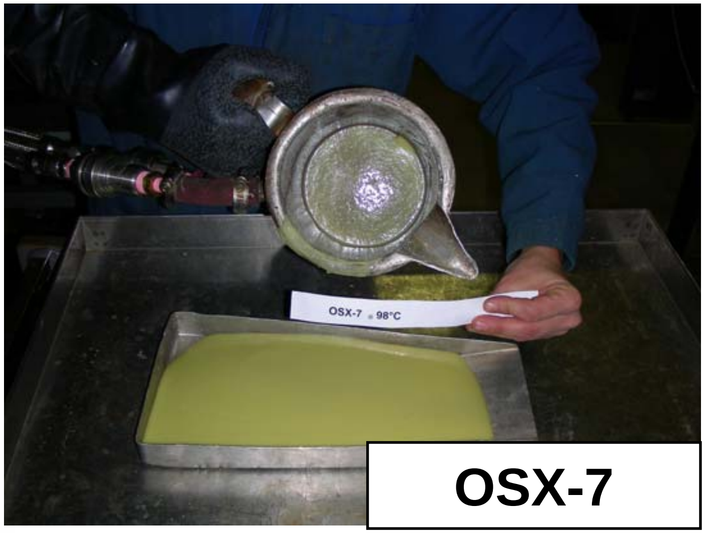
- **Viscosities measurements**

Formulations	OSX-7	OSX-8	PAX-34	Comp B
Test temperature	98°C (208°F)	98°C (208°F)	98°C (208°F)	93°C (199°F)
Initial viscosity (cP)	3040	1440	880	700-1000
Viscosity after 7.5 minutes (cP)	3286	1520	1040	1000-1400
Viscosity after 15 minutes (cP)	3440	1680	2720	2000-2400

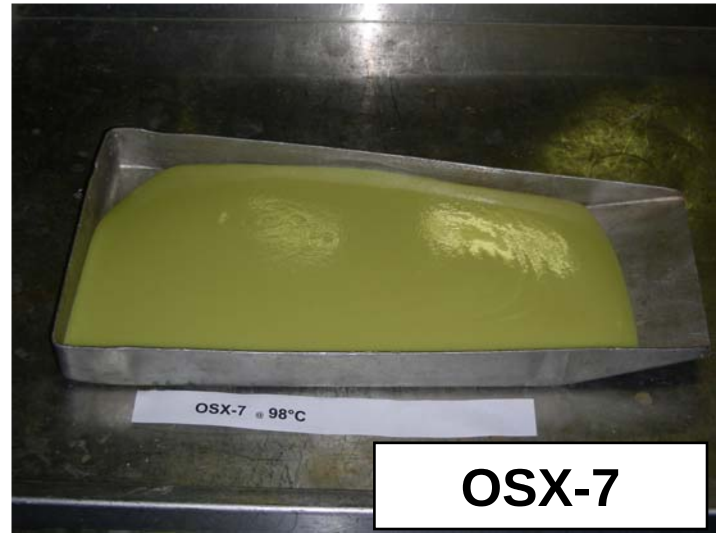
Viscosity and Sedimentation Testing

- **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
- **OSX-7: appears homogeneous and flows steadily.**
- **OSX-8: Visual segregation of constituents visible during pouring. It is very liquid at first and more viscous towards the end.**

Viscosity and Sedimentation Testing

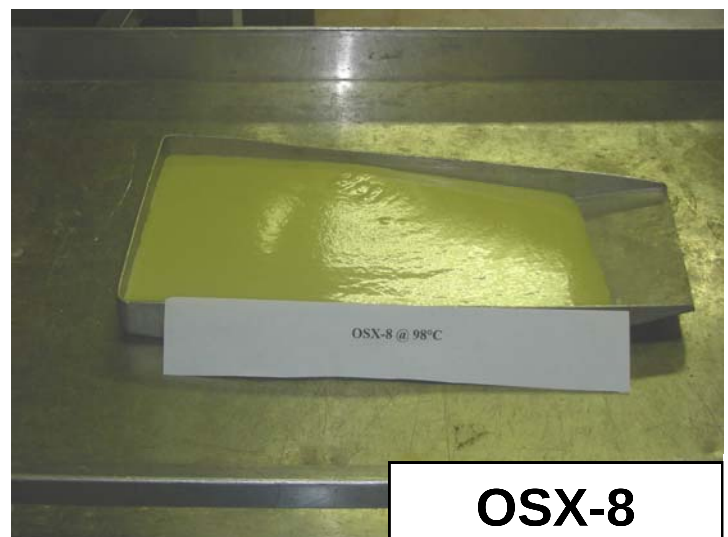


OSX-7



OSX-7

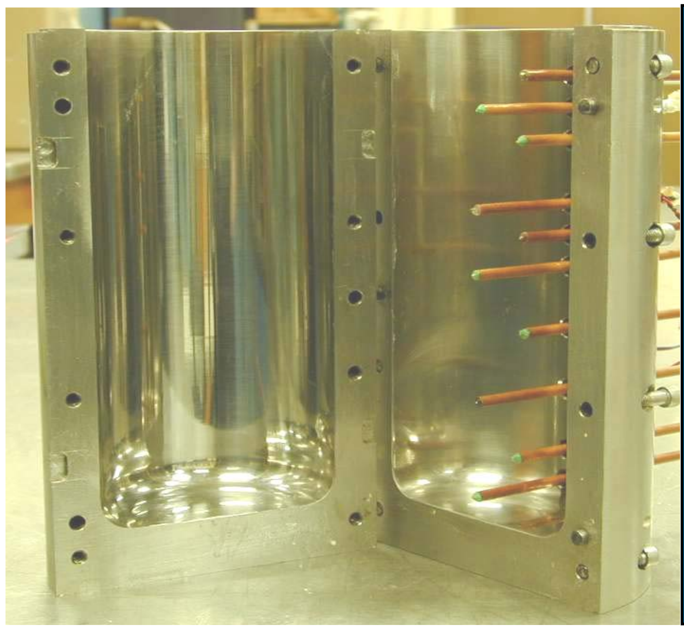
OSX-8

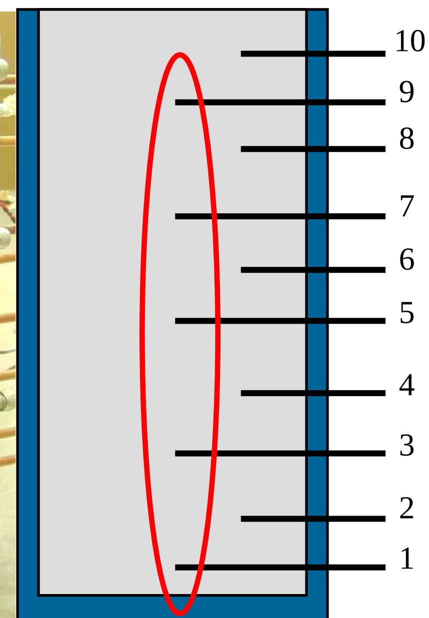


OSX-8

Thermal Characterization

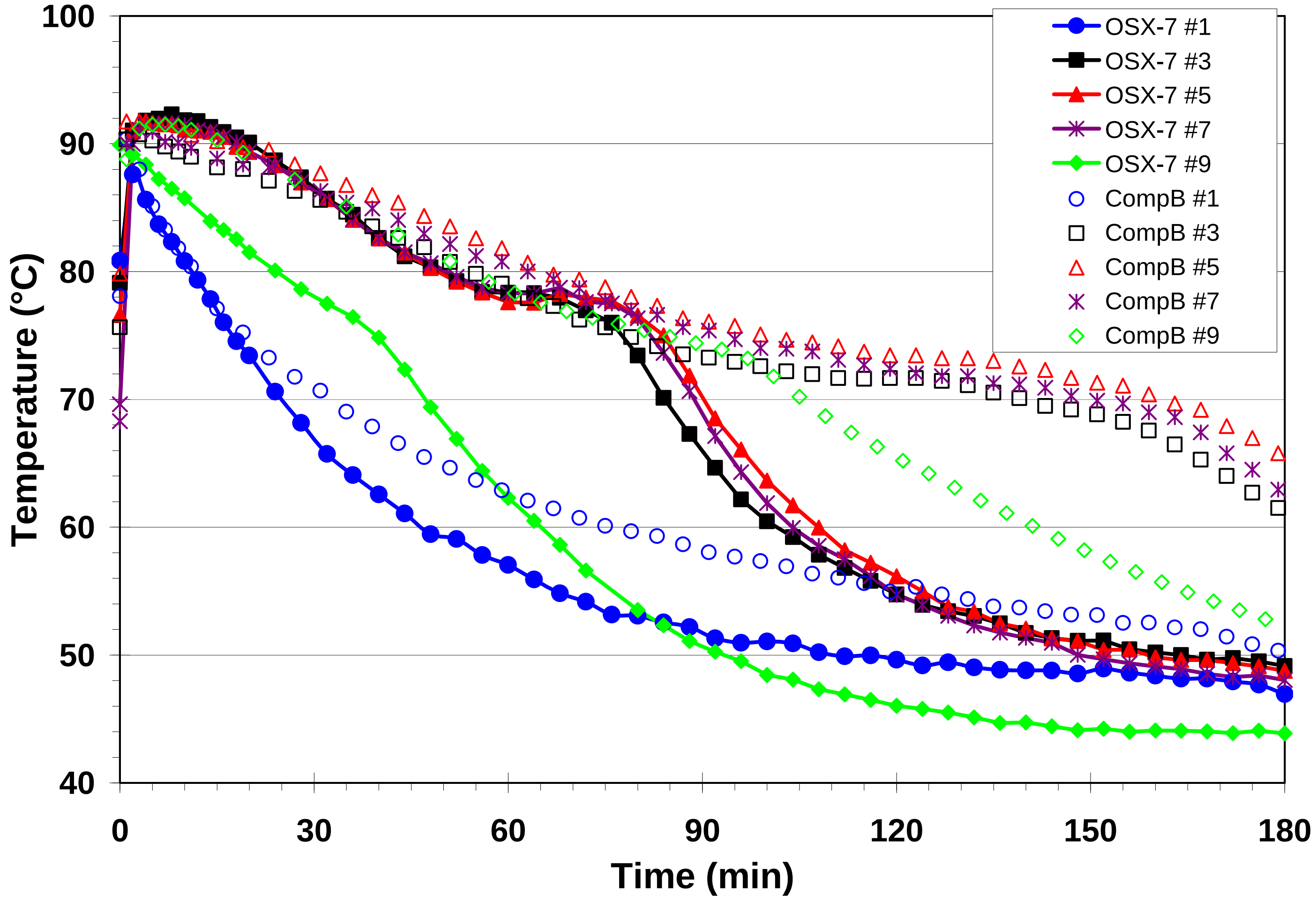
- With melt-poured formulations, controlled solidification is required to prevent formation of defects in the cast.
- The thermal behaviour is studied using a split mould cylinder loaded with the formulation. The temperature profile is recorded and material shrinkage is observed.





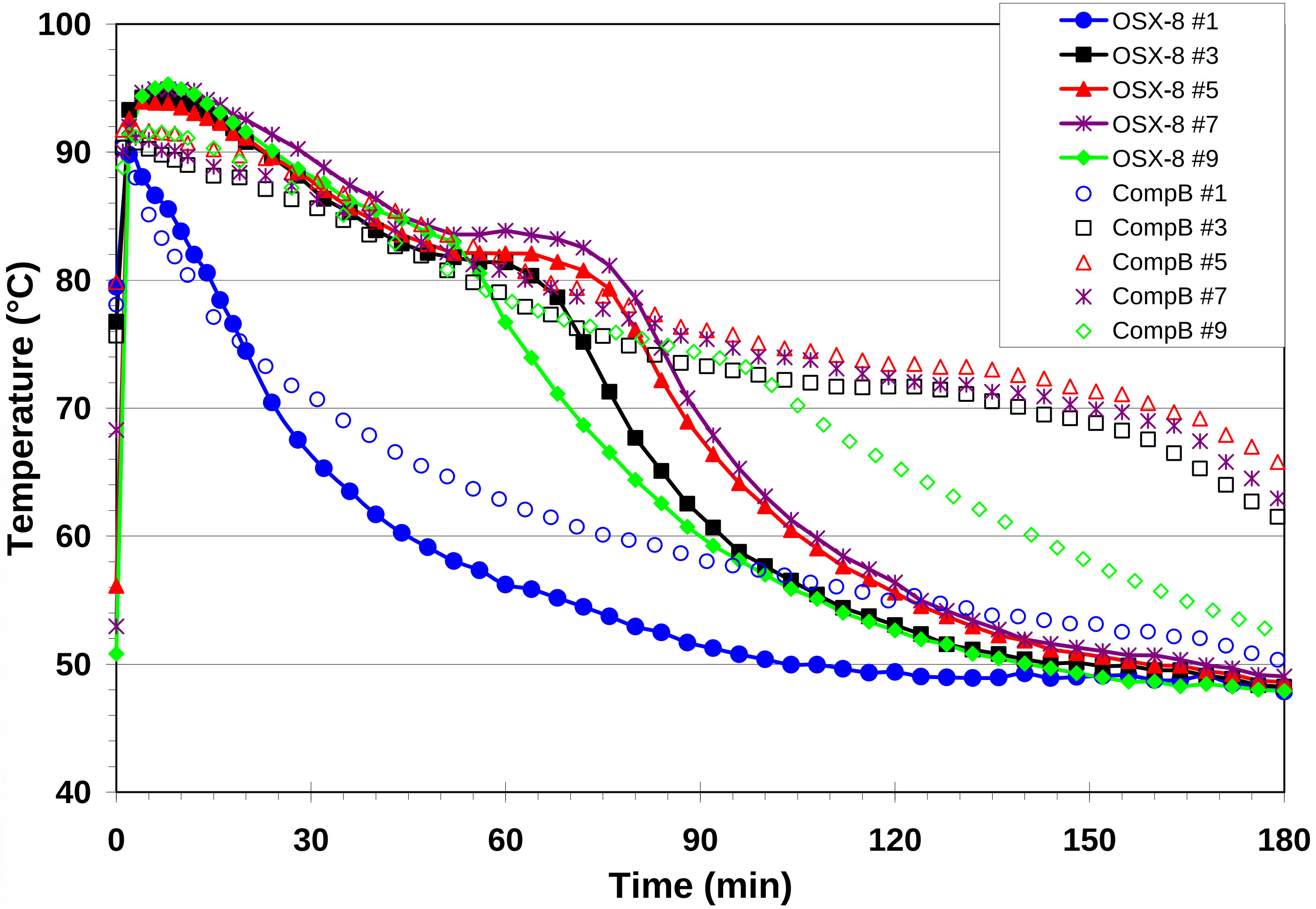
Thermal Characterization

- OSX-7 – Center Thermocouples



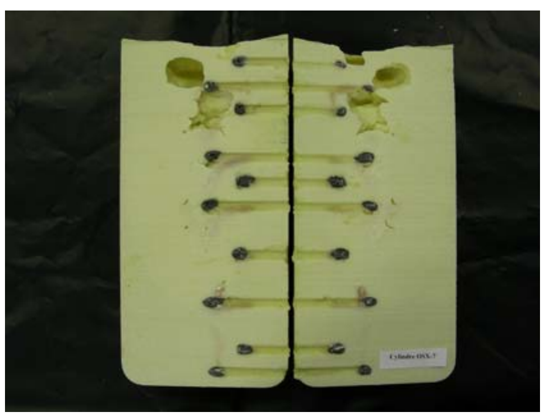
Thermal Characterization

- OSX-8 – Center Thermocouples



Thermal Characterization

- **OSX-7 and OSX-8 cool and solidify much faster than Composition B**
- **The charges were removed from the split-mould cylinder and sectioned along their longitudinal axis.**
  - Both OSX-7 and OSX-8 shrink less than Composition B. The charge had a large cavity with a diameter of ≈35 mm and other small cavities below the central cavity.

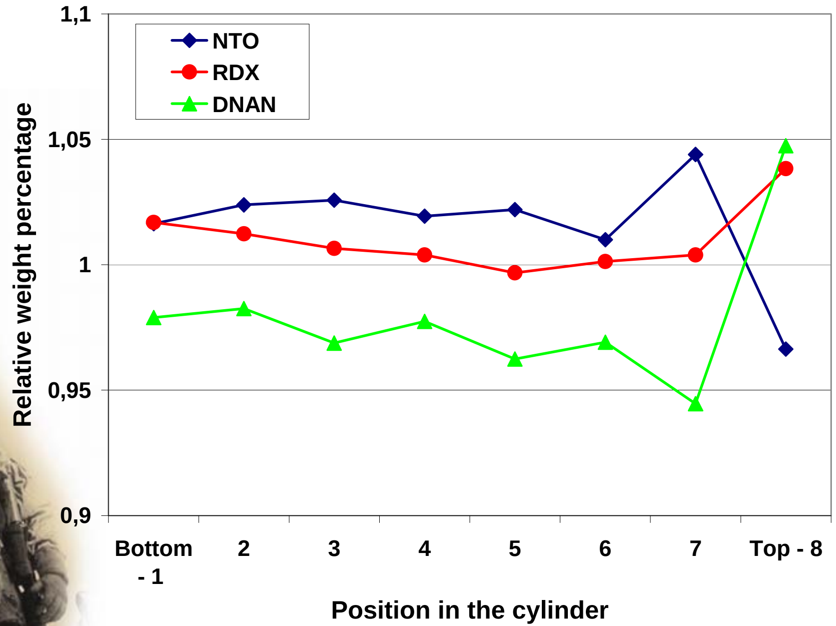


OSX-7

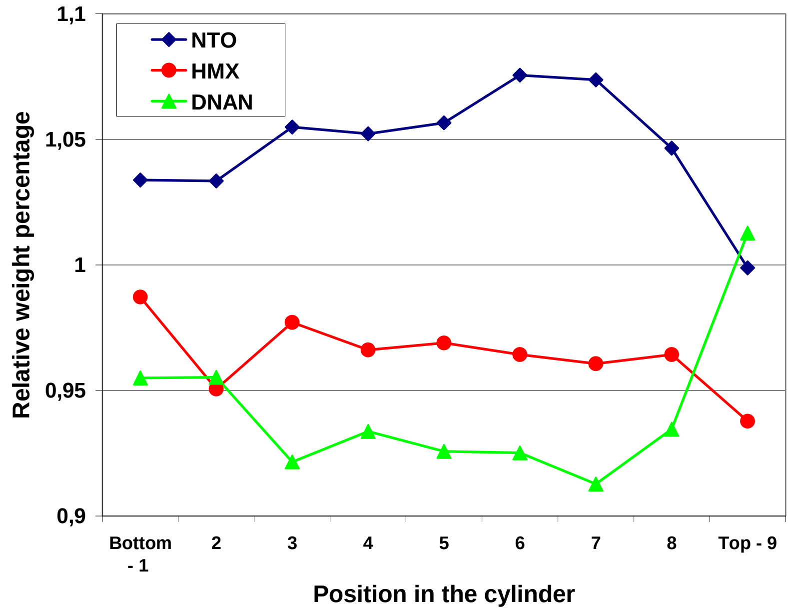
OSX-8

Sedimentation studies

- **Relative percentages of components from samples taken in the thermal characterization cylinder compared to the initial values in the composition.**
  - OSX-7 is more viscous leading to less variations
  - Ingredients variations are small compared to composition B



OSX-7



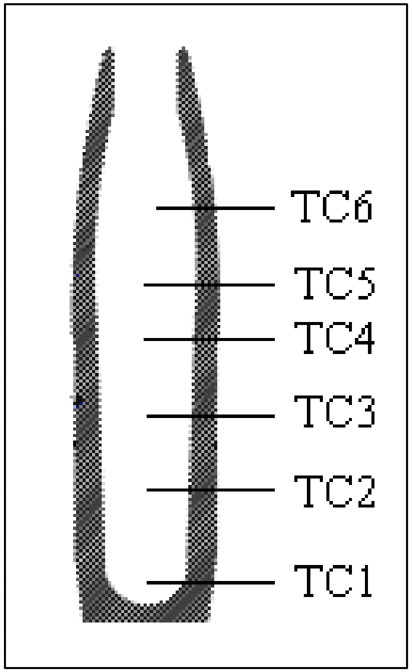
OSX-8

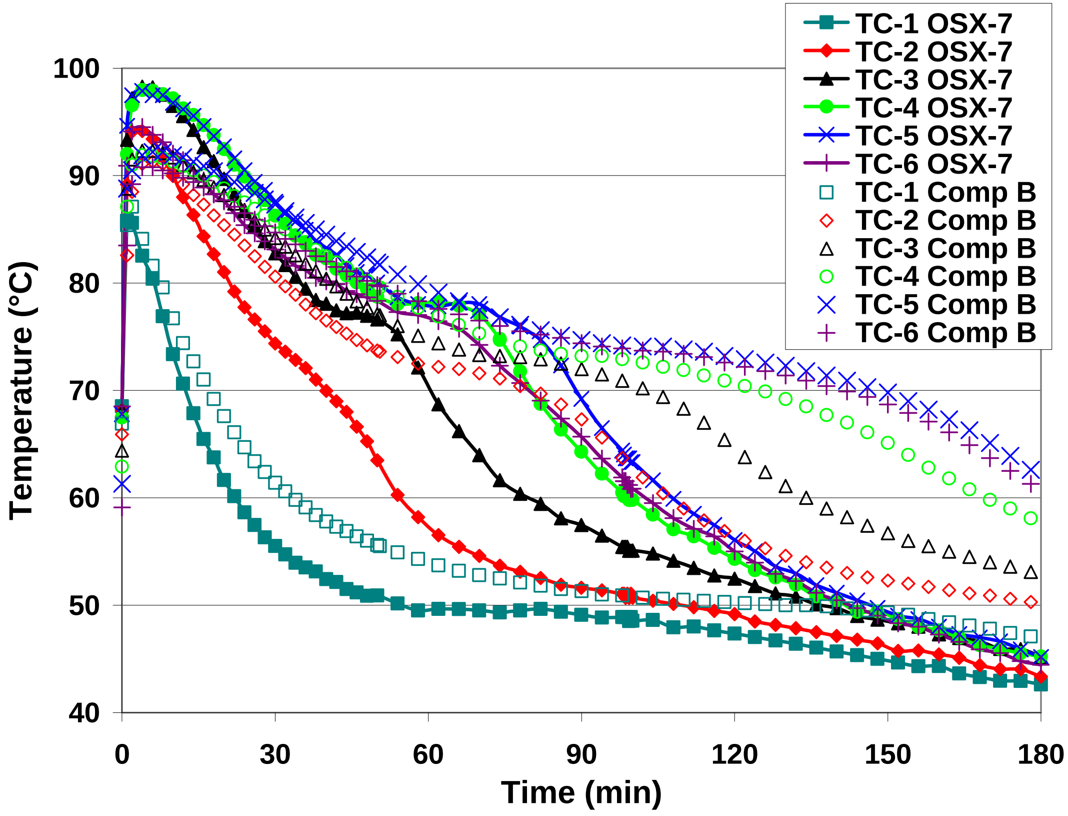
Shell Body Loading

- 105 mm HE M1 shells were loaded using standard process conditions, but at a higher loading temperature for OSX-7 and OSX-8.
- A shell body instrumented with 6 thermocouples (located at 1.2, 3.7, 5.7, 7.7, 9.2 and 11.2 in from base) was included to record the cooling temperature profile.
- Radiographic inspection was performed on the loaded shell bodies.

Shell Body Loading

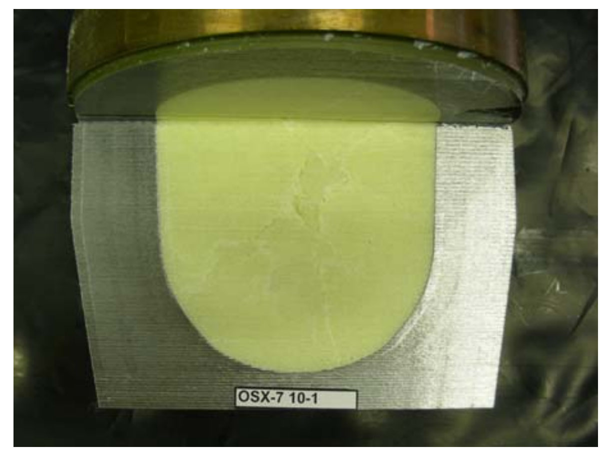
➢ **OSX-7: Formulation solidifies much faster than composition B (60 minutes faster).**





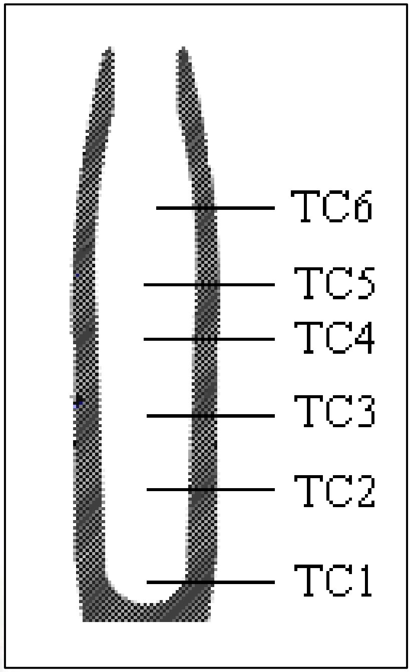
Shell Body Loading

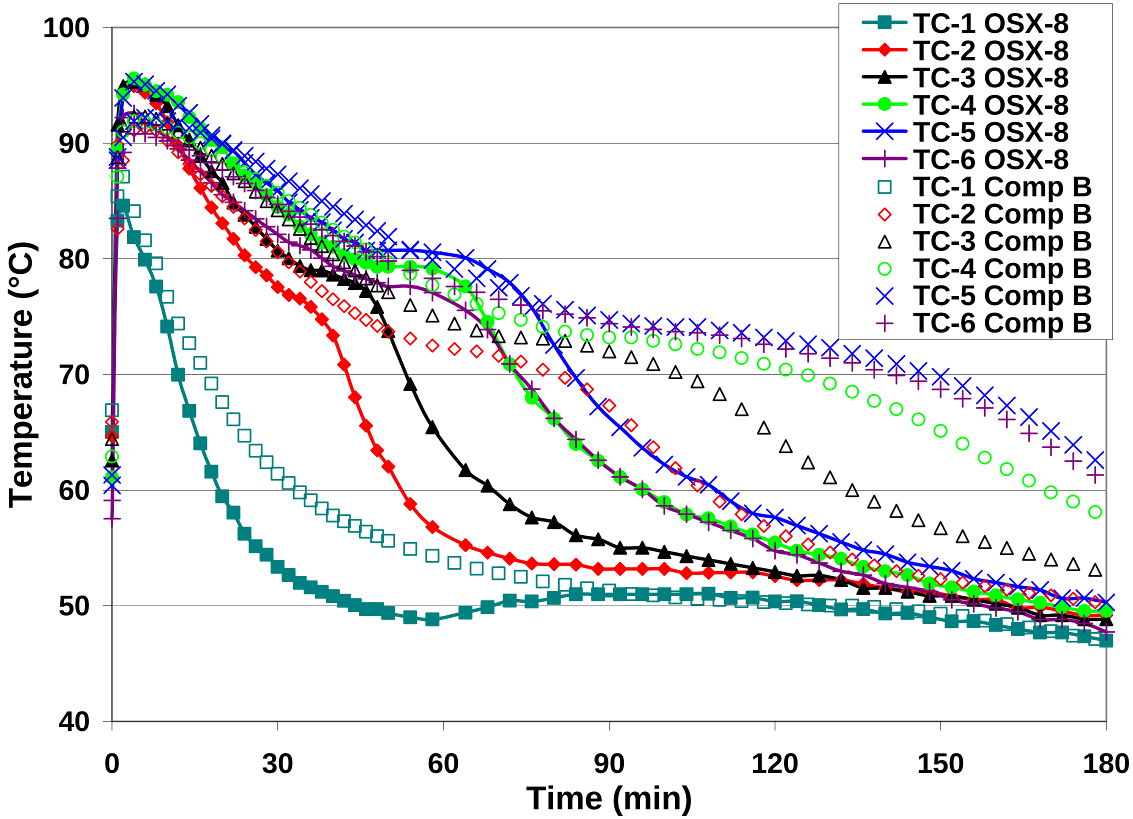
- **OSX-7: Filling results**
  - Good filling quality free of major casting defects with only minimal adjustments of composition B parameters and no change to the equipment.
  - Strong wall adherence in the bottom section.
  - Minimal acceptable cavities to be solved in future DOE studies



Shell Body Loading

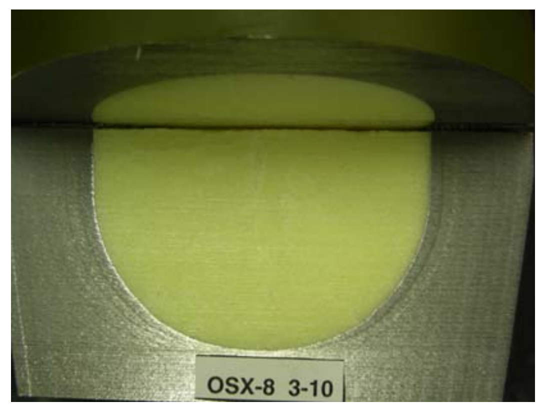
- ➢ **OSX-8: Formulation solidifies much faster than composition B and similar to OSX-7 (60 minutes faster)**





Shell Body Loading

- **OSX-8: Filling results**
  - Good filling quality free of major casting defects with only minimal adjustments of composition B parameters and no change to the equipment.
  - Strong wall adherence in the bottom section.



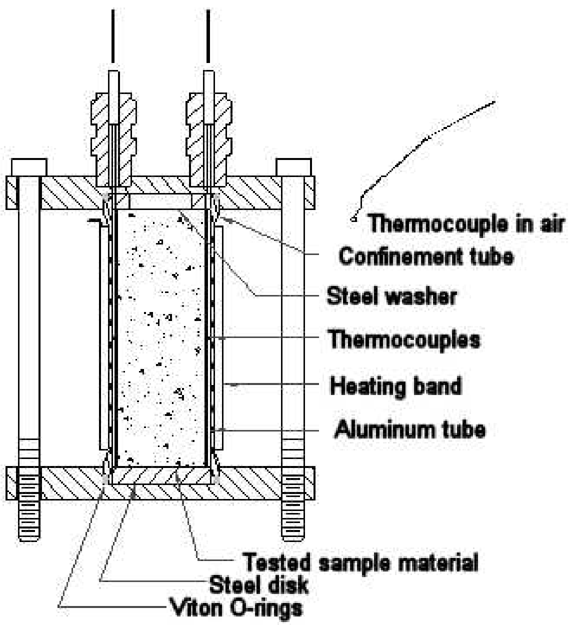
Mechanical properties

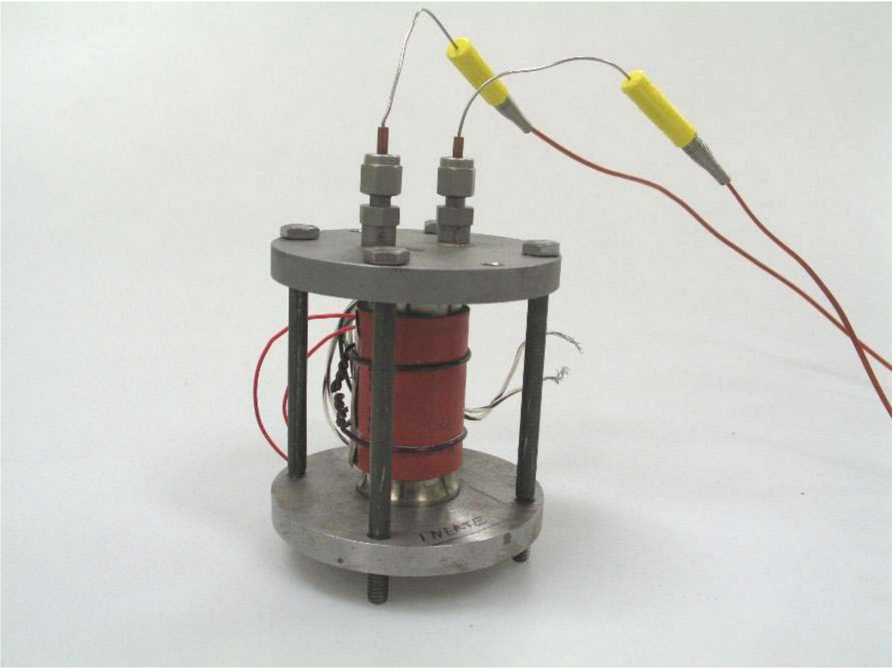
- **Mechanical properties in compression**

Property	OSX-7	OSX-8	Comp B
Maximum stress (S_m) [MPa]	18.9 ± 1.6	17.8 ± 1.3	8.1 ± 1.8
Strain at maximum stress (e_m) [%]	2.5 ± 0.3	2.5 ± 0.1	2.0 ± 0.3
Young's modulus (M) [MPa]	1708 ± 281	1436 ± 236	840 ± 147
Stress at rupture (S_R) [MPa]	9.5 ± 0.8	8.9 ± 0.7	4.0 ± 0.9
Strain at rupture (e_R) [%]	3.5 ± 0.4	3.3 ± 0.2	2.7 ± 0.1

Variable Confinement Cook-off Test

➢ **VCCT equipment**

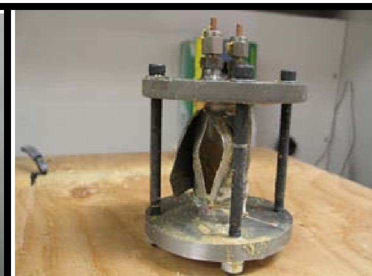




Variable confinement cook-off tests

➢ Results

Composition	0.39mm (0.0155") confinement		1.19mm (0.045") confinement	
	Reaction T°	Reaction type	Reaction T°	Reaction type
OSX-7	182°C (360°F)	V	179°C (354°F)	V
OSX-8	199°C (390°F)	V	199°C (390°F)	V
Composition B	184°C (363°F)	III	183°C (361°F)	III




0.39 mm (0.0155")	1.19mm (0.045")	0.39 mm (0.0155")	1.19mm (0.045")
Composition B		OSX-7	

Summary and Future work

- **Two IM DNAN based melt-pour formulations (OSX-7 and OSX-8) were studied in GD-OTS Canada pilot plant equipment and characterized.**

- **Both OSX-7 and OSX-8 exhibit higher melting point, higher viscosity and faster crystallization but the actual GD-OTS Canada modified Meissner process can be used without modification to the equipment and minor adjustments to the parameters to fill projectiles as shown in studies on 105mm M1 filling.**

- **Both OSX-7 and OSX-8 settle less than typical composition B.**

- **Both formulations present mechanical properties in compression about twice as good as composition B.**

- **Variable confinement Cook-off Tests indicate that OSX-7 and OSX-8 better withstand cook-off tests (burning vs explosion for the confinement tested)**

- **Future work planned: Additional characterization studies: detonation properties, physical properties during ageing, LSGT, filling of other projectiles, IM tests.**