A Reduced Toxicity Deterrent for Single Base Propellants

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Introduction

New Deterrent – Reduced Toxicity

The aim of our research was to investigate and demonstrate new reduced toxicity deterrent technologies that could be used in single base propellant applications.

- Improve HSE impacts in manufacture and with customer exposure
- Future proof propellant range (eg. REACH Compliant)
- Enhance Performance - Improved burn rate moderation

Introduction

Dinitrotoluene (DNT) – HSE issues and performance limitations

- Exposure to DNT in manufacture, handling and use, environmental impacts – toxic, suspected carcinogen
- A substance of concern under REACH, DIRECTIVE 2003/34/EC. This is a pre-requisite to total ban in Europe and possibly USA and Australia in the future.
- Optimisation of propellants with DNT is limited based on ability to moderate burn in the effective coating range.

New propellant formulations are required in order to obtain high performance products, improve efficiency and meet more stringent safety, toxicity and environmental impact requirements.

Rifle Propellants

Single-Based Propellant

A single based propellant has nitrocellulose as its chief explosives ingredient.

Double-Based Propellant

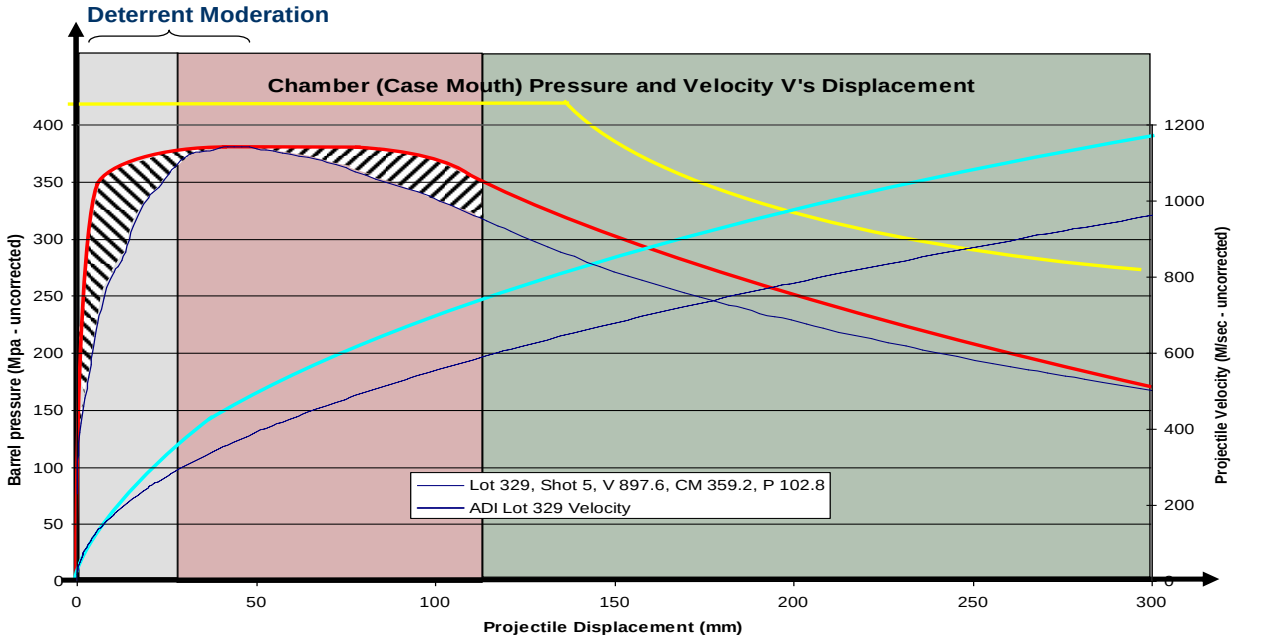
Double-based propellants consist of nitrocellulose with nitroglycerin or other liquid organic nitrate explosives added.

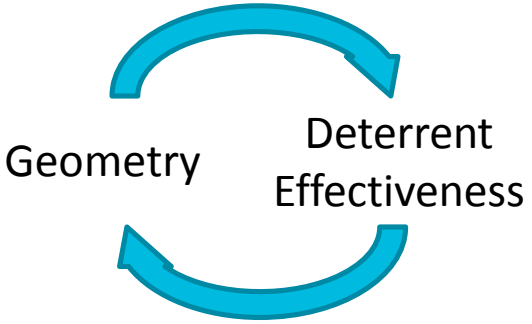
Stabilizers and other additives are used to control the chemical stability and enhance the propellant's properties for both types.

Small Rifle Propellant (eg.5.56m)

Large Rifle Propellant (eg. 50 Cal)

Propellant Design





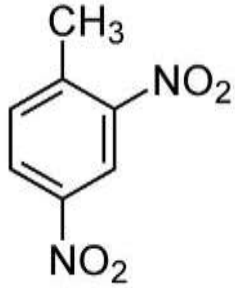
What is Required

- **Optimized Geometry**
- **↑ Charge weight Progressive burn rate**

What makes DNT a good deterrent for SB?

DNT – primarily 2,4-Dintrotoluene

- Solid - Melting point (69-71ºC)
- Melt coating (solventless), processed in a sweetie barrel ~1hr
- Coating “non-sticky” → Bulk Density
- Good chemical and ballistic stability
- Leaves little or no residue on burning
- DNT is a part plasticizer with Nitrocellulose (NC- deterrent interaction)
- Low solubility in water
- Low cost material



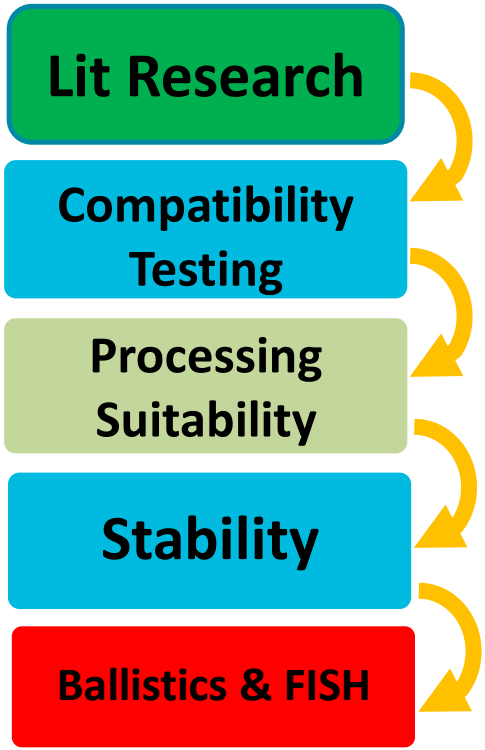
Sweetie Barrel

Deterrent Selection Considerations and Selection Process

Deterrent Considerations

- Low cost
- Can be processed using existing equipment and infrastructure – solid with high melting point (>65ºC)
- Level of plasticisation (Deterrent-NC interaction)
- Non-hydrophilic (minimal moisture uptake)
- Compatibility/Stability with Nitrocellulose
- Process viability (time for coating, stickiness, etc)
  - Diffusion – during coating process and over time
- Combustion
  - Ignitability
  - Low toxicity of combustion gases
  - Complete burn, low residue

Deterrent Selection Process



Finding Less Problematic Substances

The search for alternative ingredients

- Chemical composition - C H O N
- Reduced toxicity
  - Preferably food grade chemicals
- Solid substances
  - Melt above 65ºC and below 90ºC
- Thermodynamic Code analysis
- Minimal Waste Issues
- Low Cost

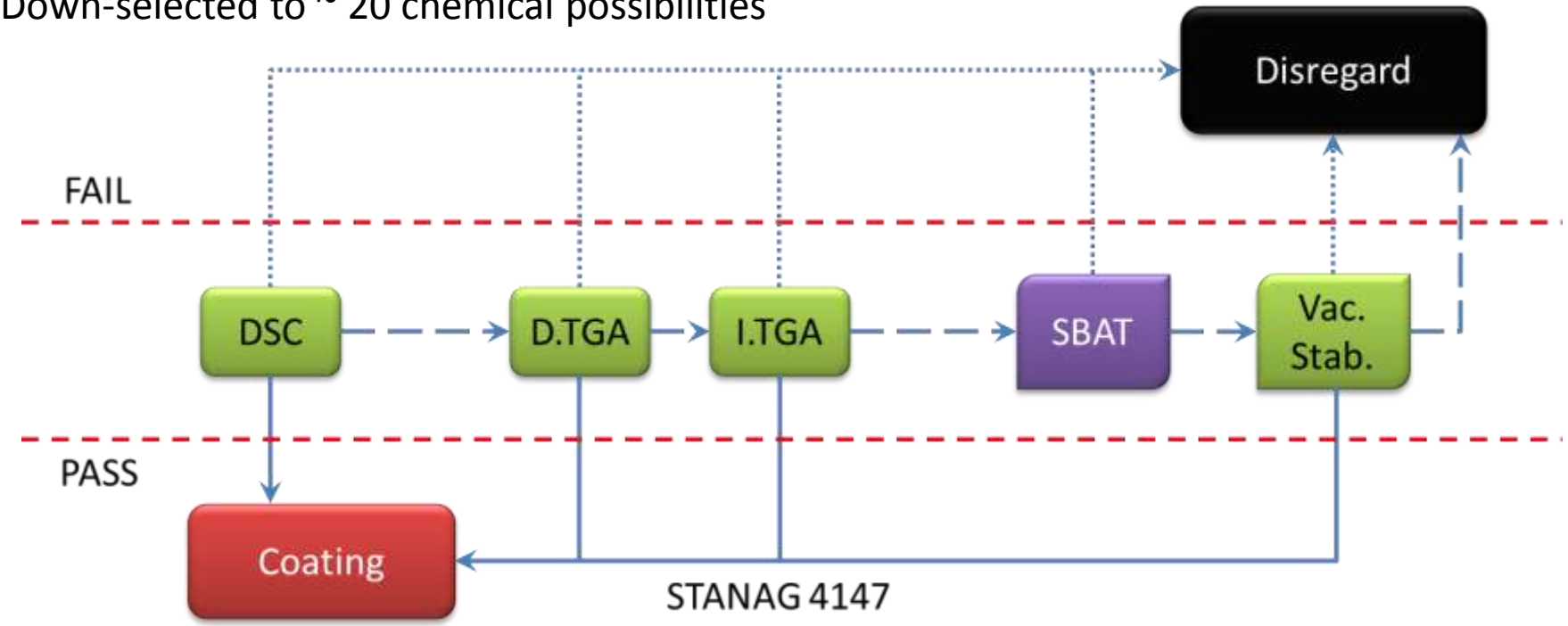
Thousands of options

~50 options

Identification of New Chemicals as Potential Deterrents

Compatibility: Screening with thermo-analytical techniques or Vac- Stab.

Down-selected to ~ 20 chemical possibilities



Down Selection: Candidates

Alternative Deterrents:

- Handful successful in coating process
- **Deterrent A**
  - **GRAS chemical**
  - **Melts and Coats well**
- Deterrent B
  - GRAS chemical
  - Melts and coats well

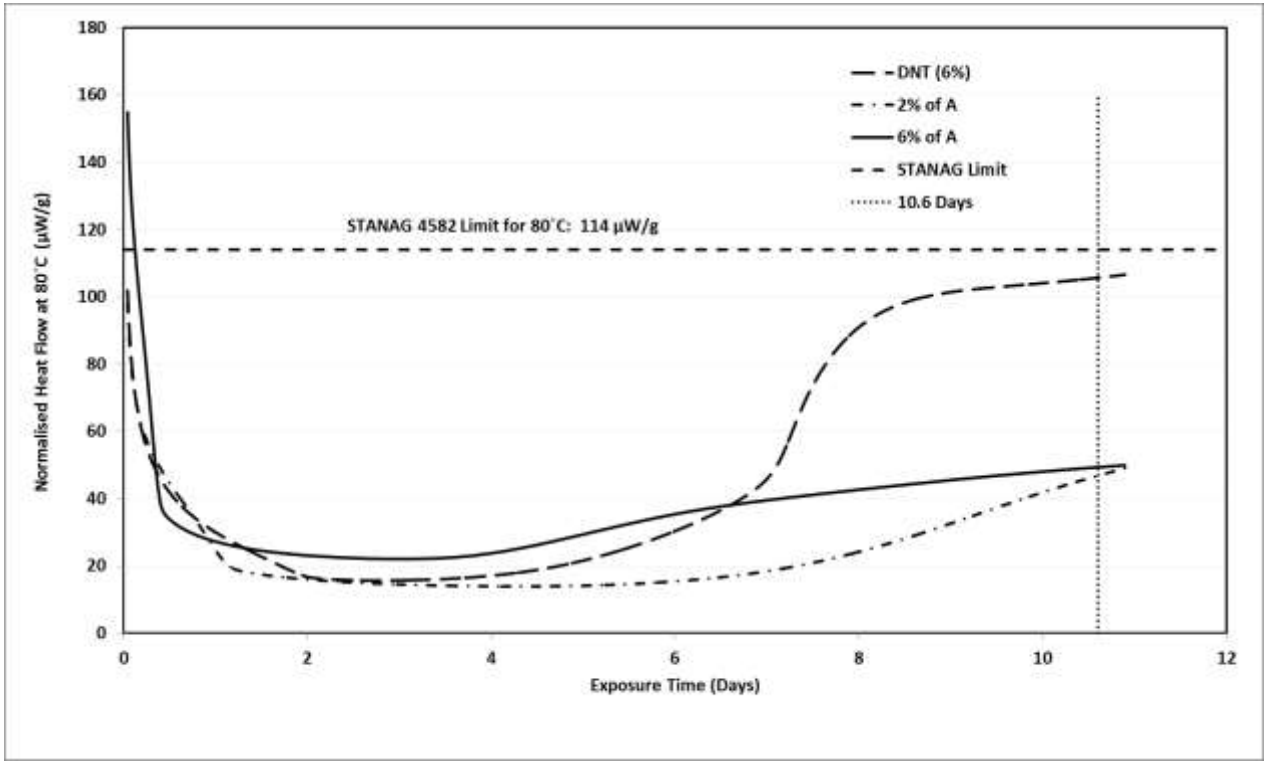
Additive	Additive A Additive B
Main Function	**Deterrent**
Health	**0 - 2**
Fire	**1**
Reactivity	**1**
Effect	Reduce toxicity Maintain or improve performance

Stability Results

	AOP-48 (80 °C)	Abel Heat (76.7 °C) min.	Methyl Violet Paper (134 °C) min.
6% DNT	-67% 10 years	18	35
2% of A	-38% 10 years	21	35
6% of A	-65% 10 years	11	25

New Deterrent is stable according to AOP48 but gives poor results with traditional spot tests.

Stability –Heat Flow Calorimetry



HFC STANAG 4582

New deterrent led to different type/number of reactions occurring during heating,

- Propellant with Deterrent A has lower heat output, indicating potential longer term stability
- Aligns with Stabiliser Depletion Test AOP48.

SBAT Stability Evaluation

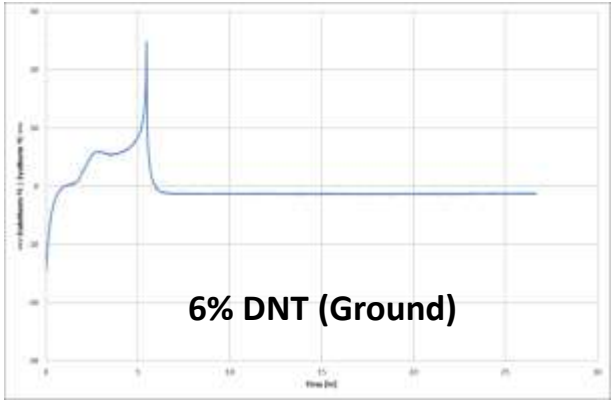
Fixed Temperature Propellant Stability Trials

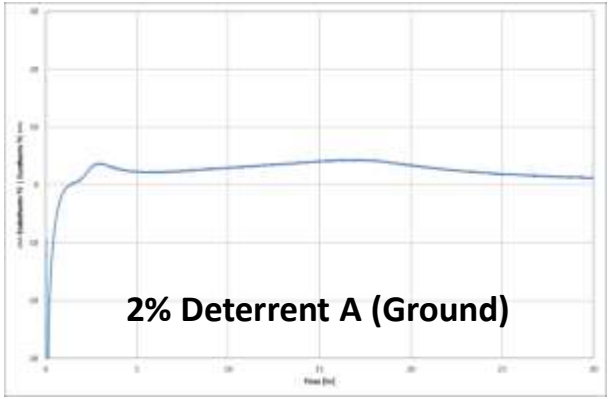
Isothermal Simulated Bulk Auto ignition Temperature (SBAT) method:

- Propellant 1.2 – 1.3 grams ground
- SBAT heated to 110 °C (corrected), samples inserted. Then temperature raised to 135°C (corrected) @ 0.2°C/min for 20+ hours

Preliminary Data:

- DNT propellant combustion after 5.5hrs, 100% weight loss
- Deterrent A propellant, no combustion after 20hrs but ~50% weight loss



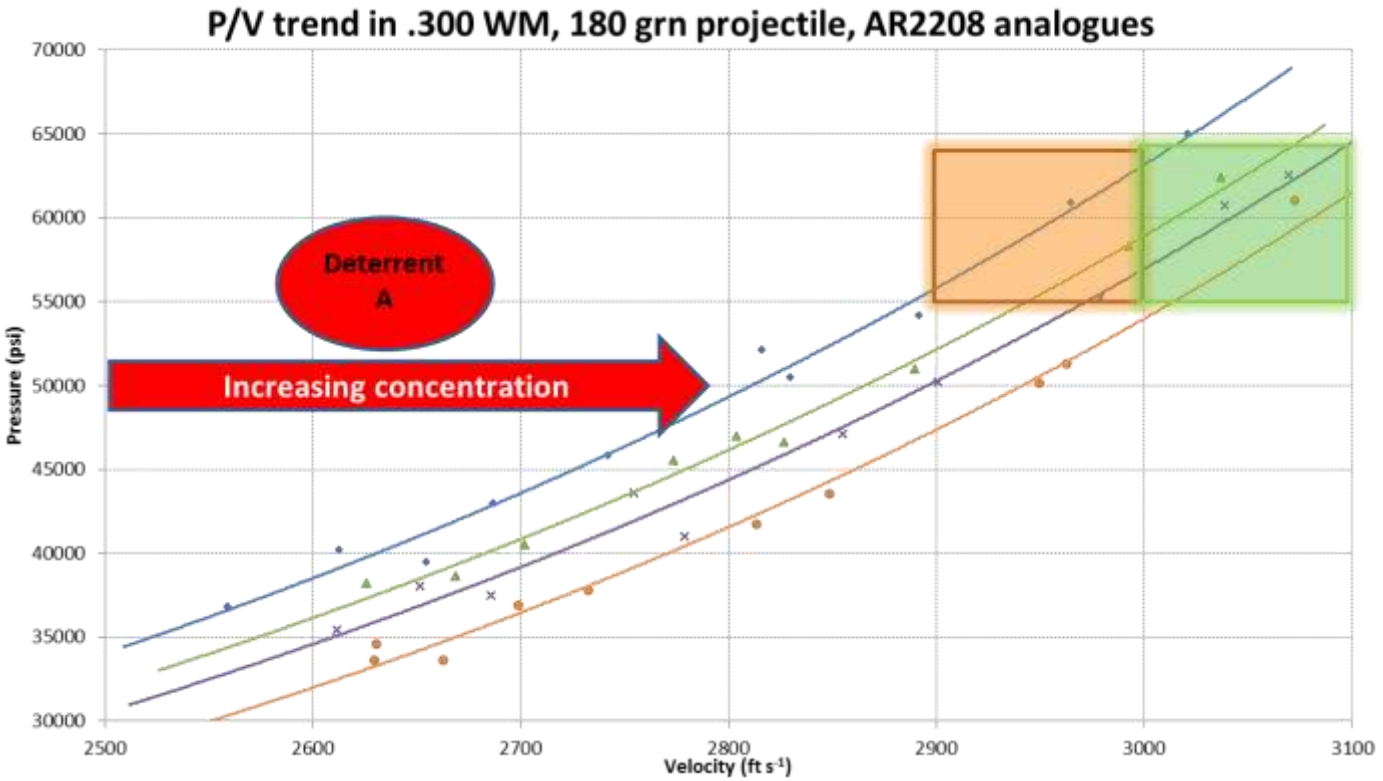


Ballistic Performance

Progressivity Benefits - Can move the performance window to the right in the P/V trend.

= Higher velocities at matched pressures

Higher % deterrent
= lower flame temperatures



Ballistics – Burn Rate Effectiveness

AR2501

H4895
(AR2206H)

Varget
(AR2208)

H4350
(AR2209)

H4831SC
(AR2213SC)

Diameter ~0.7mm
Length ~1.4mm

Diameter ~0.9mm
Length ~1.5mm

Diameter ~1.2mm
Length ~1.5mm

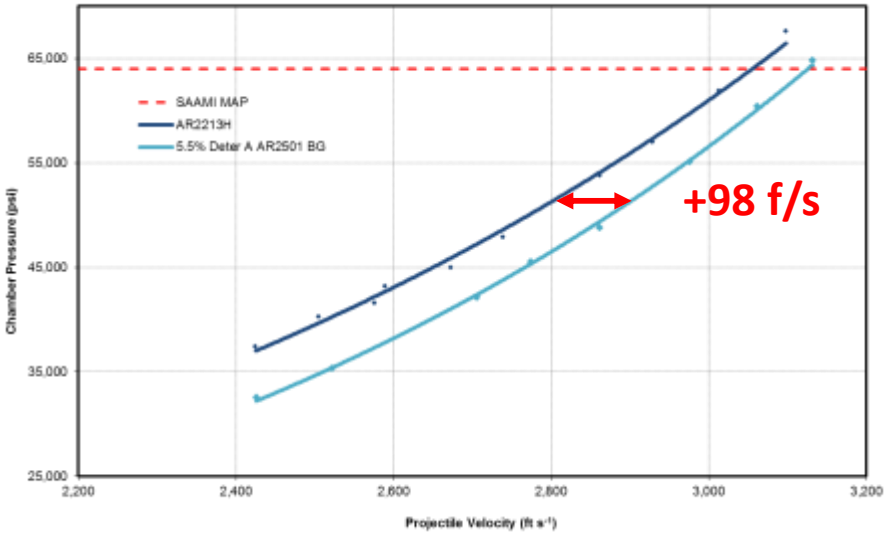
Typical Applications:

223 Rem | 308 Win | 30-06 Springfield | 300Win. Mag

Rifle Propellant Burn Rate - Fast → Slow

Ballistic Improvement Example

Pressure / Velocity Relationship:
.300Win Mag, 180-gr HSP projectile



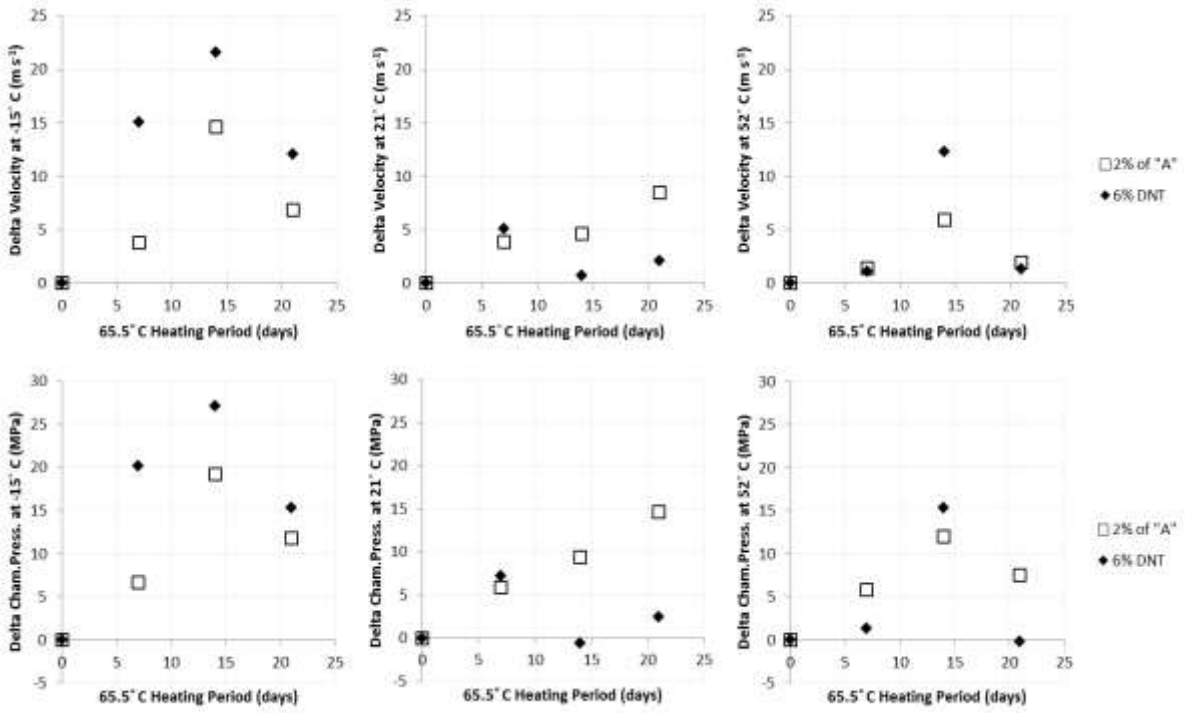
300 Winchester Magnum and 180gn Sierra GameKing	Charge Weight (gns)	Corrected Velocity (ft/s)	Corrected Pressure (PSI)
AR2213	78.0	2998	61290
AR2501 B/G 5.5% Deter A	76.5	3096	61703

Ballistic Stability of Aged Ammunition

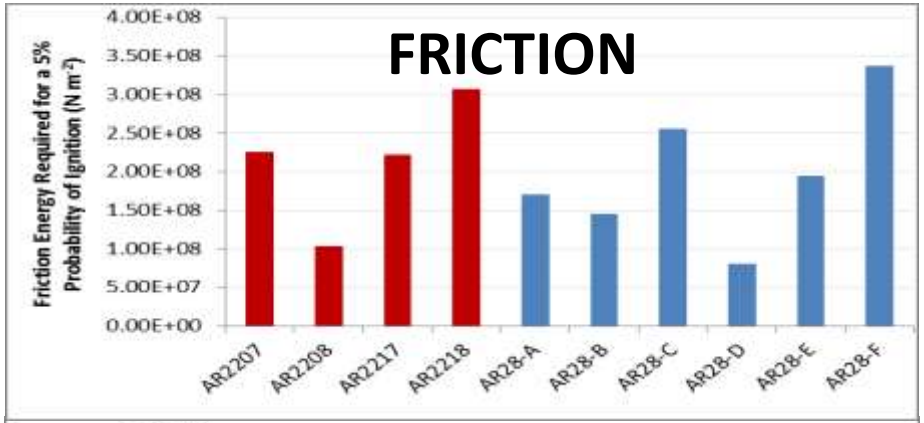
5.56 mm test platform with SS109 style projectile - Ballistic thermal spread measured at -15˚C, 21˚C and 52˚C with samples aged over a three week period at 65.5˚C.

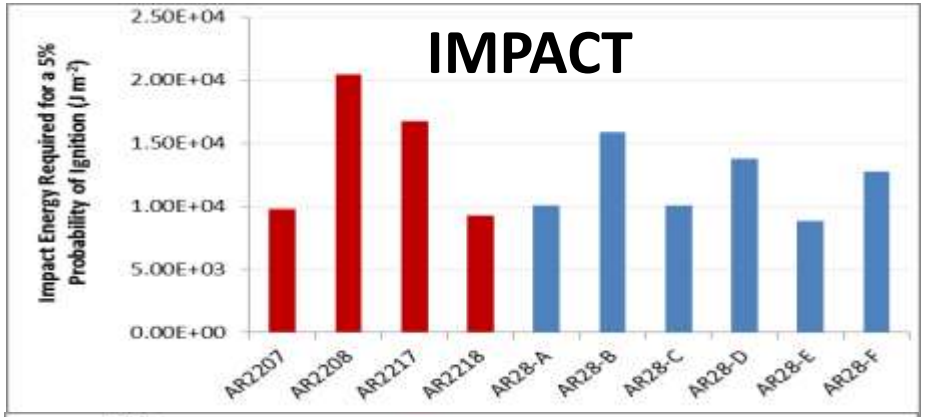
New deterrent has similar performance to DNT on propellant for:

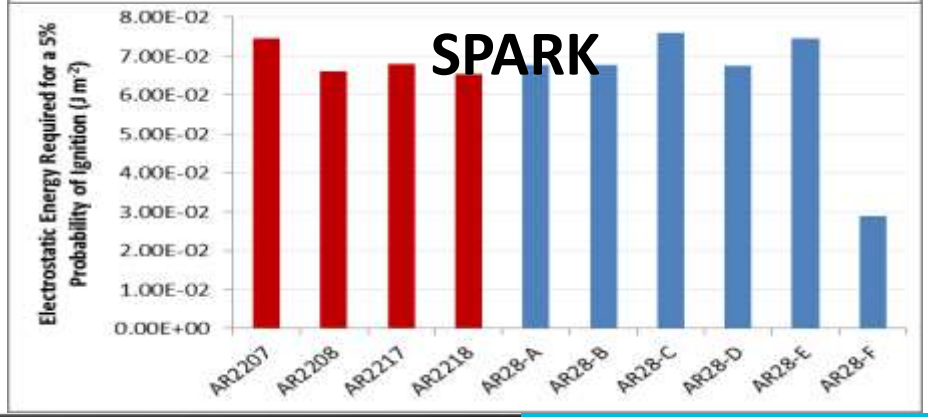
- **Velocity (<15 m/s)**
- **Pressure (<20MPa)**

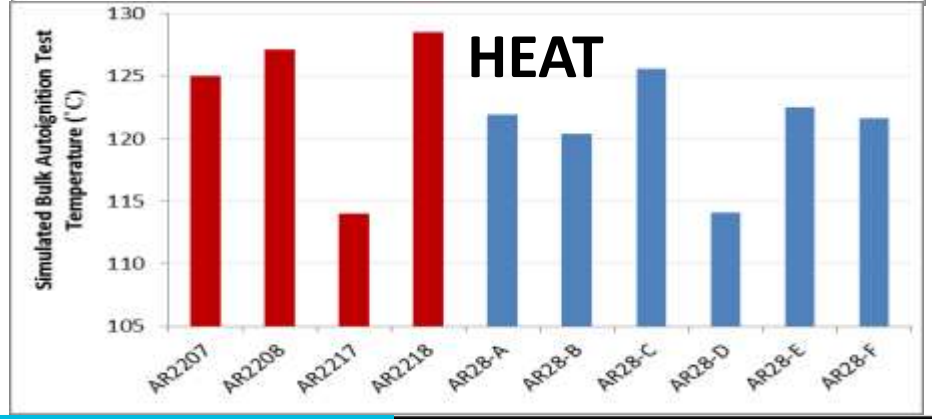


FISH testing of some development variants









Results of new deterrent (AR28-series) similar to DNT deterred AR22-series

Summary

Outcomes: New Single Base Deterrent

- ✓ **Greener Option -** Reduced HSE concerns
- ✓ Coating process is similar to current DNT
- ✓ Highly effective burn rate moderant
- ✓ Extend limits of traditional grain geometry/design (ie. for improved burn efficiency)
- ✓ Propellants ballistic performance significantly improved
- ✓ Improved shelf life

Future Work

AR28-series with new deterrent is currently undergoing product development.

New deterrent technology appears to improve propellant stability.

- Understand mechanism for stabilisation
- Understand reason for AHT and MVP results
- Find alternative spot test (eg. B&J)

The End

Thankyou for your attention!

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