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M1002

# Development of a Solventless Propellant for use in 120 mm Tank Training Rounds

M865

**The National Defense Industrial Association's Joint Armaments Conference, Exhibition, & Firing Demonstration**

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# Outline

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## M14 Replacement in 120 mm Tank Training Rounds

- Program Summary
- Background
- Program Requirements
- Solventless Propellant Production Process
- Previous Accomplishments with PAP8386 Propellant
- Current M14 Replacement Approach
    - DEGDN-free PAP8386
    - Modified PAP8386
- Formulations and Closed Bomb results for DEGDN-free PAP8386
- Future Work
- Conclusions

# Program Summary

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- **<u>Sponsor:</u> PM MAS**
- **<u>Customer</u>: JMC/ARDEC**
    - **End User (Army and USMC)**
- **<u>Funding Source</u>: Army and USMC**
- **<u>Contracts</u>:**
    - **JMC → ATK AW → ATK ES**
- **<u>Objective</u>: Per request of PM Large Caliber Ammunition, develop a solventless propellant that meets the M865 and M1002 ballistic requirements, and can be used with the suite of 120 mm future rounds**
    - **Optimize solventless formulation**
    - **Optimize propellant web**
    - **Demonstrate desired ballistics of M14 replacement propellant**

# Background

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## M14 Propellant Characteristics

| Ingredient, wt. % | M14 |
|---|---|
| NC, 13.15% N | 90.0   2.0 |
| DNT | 8.0   2.0 |
| DBP | 2.0   1.0 |
| DPA (added) | 1.05   0.15 |
| Graphite (added) | 0.06   0.04 |
| Residual Solvent | 0.7 Max |
| Moisture | 0.6   0.2 |
| Flame Temp., [K] | 2774 |
| Force, [J/g] | 995 |
| Abs. Density, [g/cc] | 1.60 |

## M865 TPCSDS-T

Projectile Weight = 5.50 kg

MV (21   C) = 1700    20 m/s

MV (52   C) = 1740    20 m/s

MV (-32   C) = 1620    30 m/s

Pressure (63   C) <= 5900 bars

M14 Charge Weight = 7.2 kg

## M14 Propellant Drawbacks

- Damaged cartridges may vent residual solvent (diethyl ether)
- DNT, DBP and DPA are environmentally undesirable
- IM Properties poor compared with tactical ammunition

## M1002 MPAT-TP-T

Projectile Weight = 10.55 kg

MV (21   C) = 1375    10 m/s

MV (52   C) = 1404    10 m/s

MV (-32   C) = 1335    10 m/s

Pressure (63   C) <= 6400 bars

M14 Charge Weight = 7.6 kg

# Program Objectives



1. Eliminate (or reduce) residual solvents.
2. Meet existing ballistic requirements for the M865 and M1002.
   - **Min. M1002 velocity** at -32 C
   - **Meet velocity tolerance** from -32 C to +52 C
   - **Average max. pressure** at +63 C at least 3 Std Dev. below the fatigue limit of the M256 gun tube (7000 bars)
   - **Meet negative delta p requirements** of ITOP 4-2-504(2) and not affect safety or structural integrity
   - **Meet ballistic requirements** per DTL 14000022
3. IM standards equivalent or better for each round.
4. Affordable solution relative to existing M14 costs.
5. Environmentally friendly formulation and process.
6. Producible at the quantities required to meet near term cartridge needs.
7. Propellant compatible with existing cartridge materials.
8. Propellant shall not negatively impact barrel/gun tube life.
9. Propellant storage life and hazard classification meet existing requirements.

Solventless process eliminates risk of damaged cartridge venting ether


Solventless propellant manufacturing process at the Radford Army Ammunition Plant

# Previous Work With PAP8386 Propellant



| Thermochemical Parameter | Value |
|---|---|
| Flame Temperature, [K] | 2948 |
| Force, [J/g] | 1063.6 |
| Gas Molecular Weight, [g/gmol] | 23.049 |
| Covolume, [cc/g] | 1.042 |
| Frozen Gamma | 1.244 |

- **Solventless Manufacture**
  - Completely Eliminates Potential of Solvent Vapor Ignition Within Round
- **Material Properties Similar to JA2**
  - Improved Impact Sensitivity
- **Environmentally-Friendly Formulation**
  - Eliminates DNT, DPA, DBP, and all VOC's
- **Same Ingredients as JA2 and RPD-380**
  - Compatible with existing systems
  - 1.3c Hazard Classification
  - Similar Storage Life
- **Flame Temperature < 3000 K**
  - Low barrel Erosion

# M865 Performance Using PAP8386 Propellant

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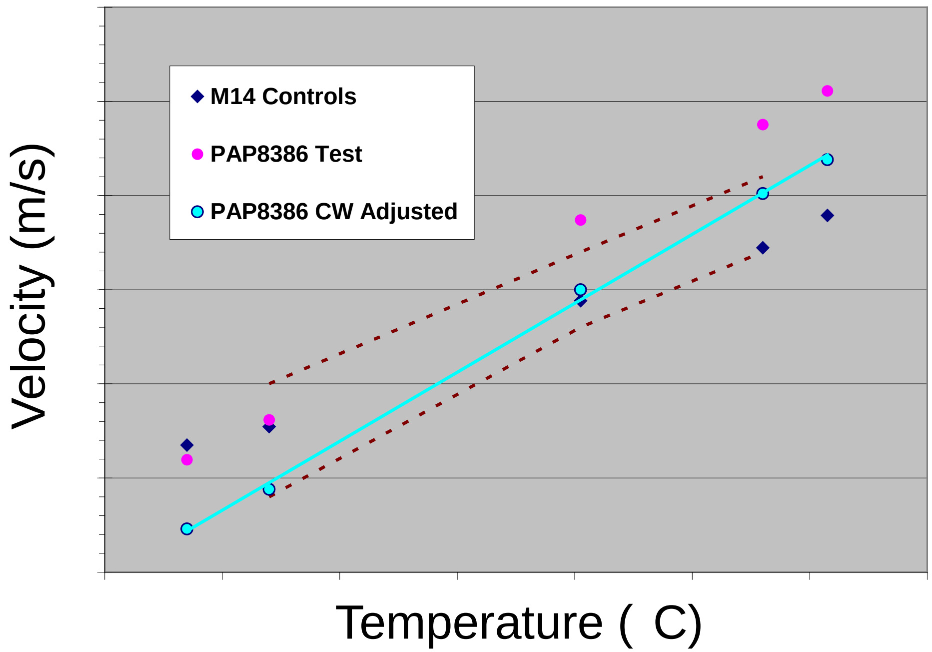
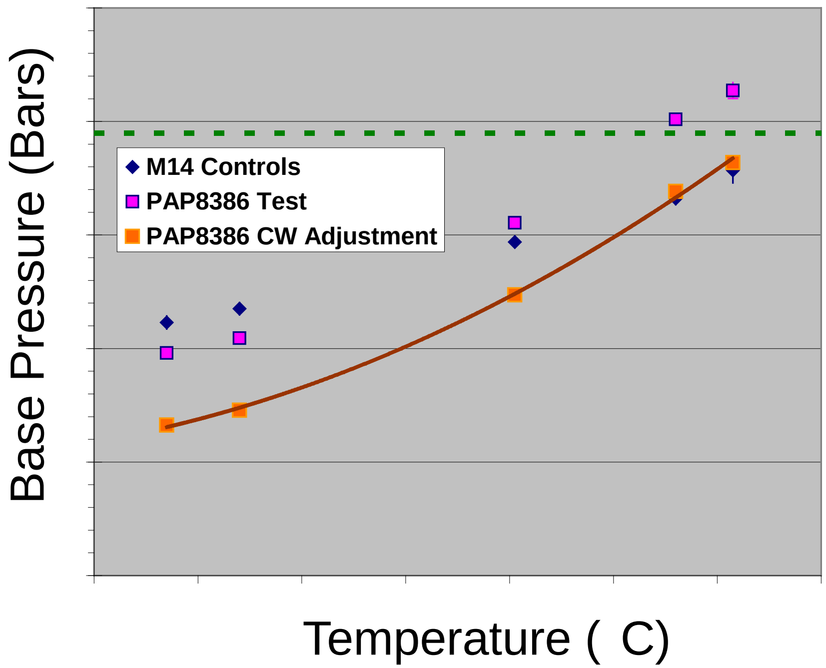



PAP8386 met M865 performance requirements for muzzle velocity




PAP8386 peak pressure is comparable to existing round

# M1002 Performance Using PAP8386 Propellant

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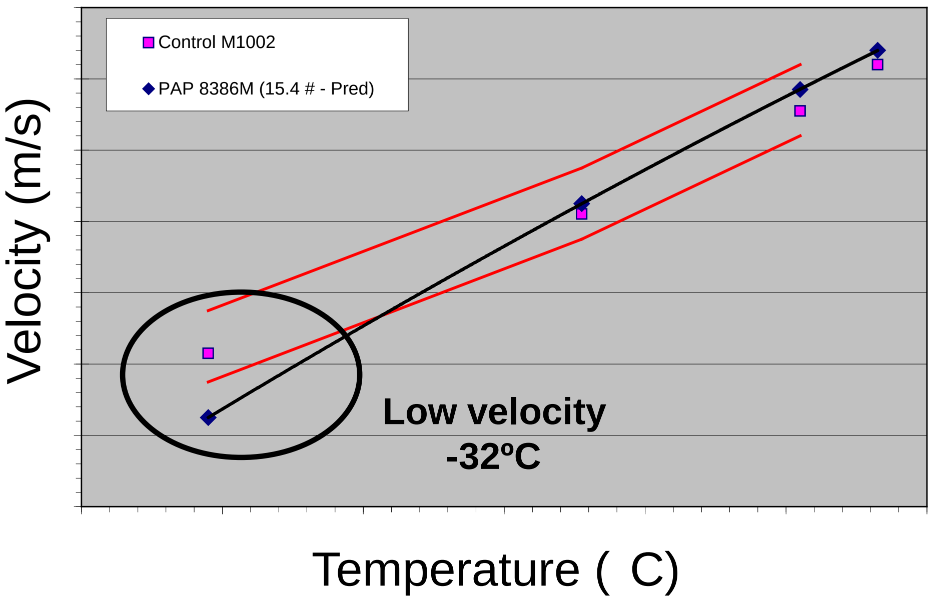
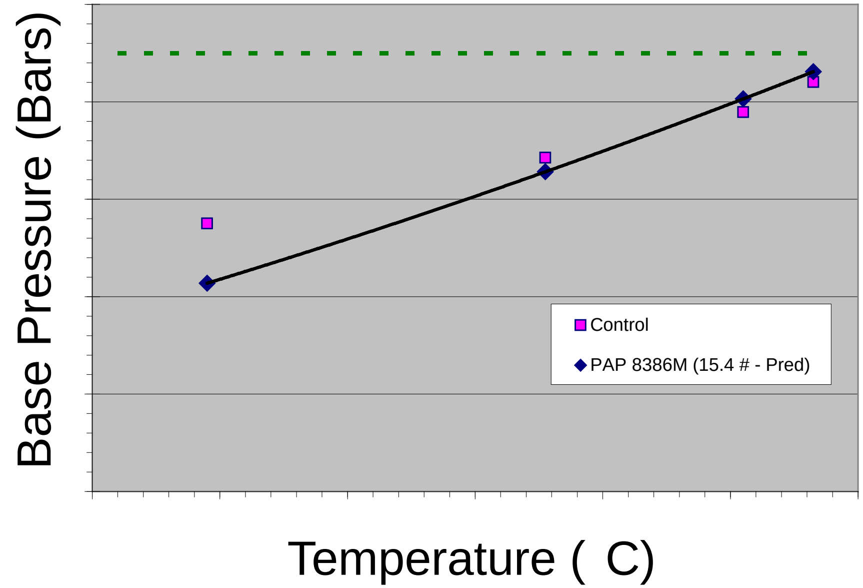



Muzzle velocity falls just below the performance window at -32   C. Further optimization is necessary.

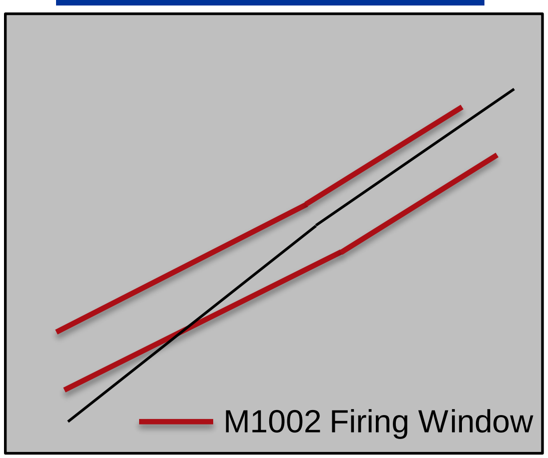
PAP8386 pressure levels are equivalent to existing round

**Results Shown are Predicted 15.4 lb Charge Weight Adjusted Based on February 2006 Firing Data At Aberdeen Test Center with a 15.6 lbs**

# Dual path

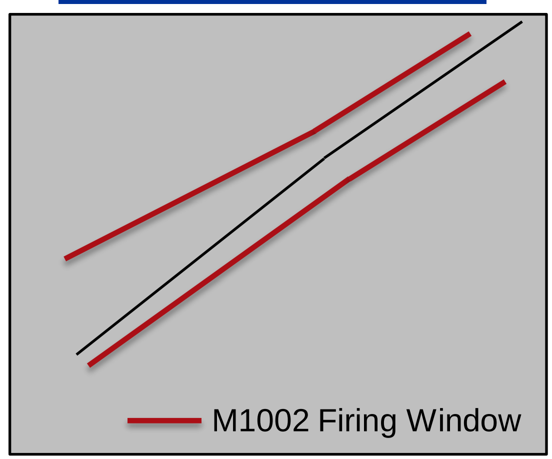
- **Preferred Path -- Replace DEGDN in PAP8386**
  - ✓ Higher technical risk, lower potential per pound cost for formulation
- **Alternate Path -- Build on previous PAP8386 work**
  - ✓ Lower technical risk, higher potential cost per pound for formulation (but less expensive than original PAP8386)
  - ✓ May require a change to the firing tables

Previous Work



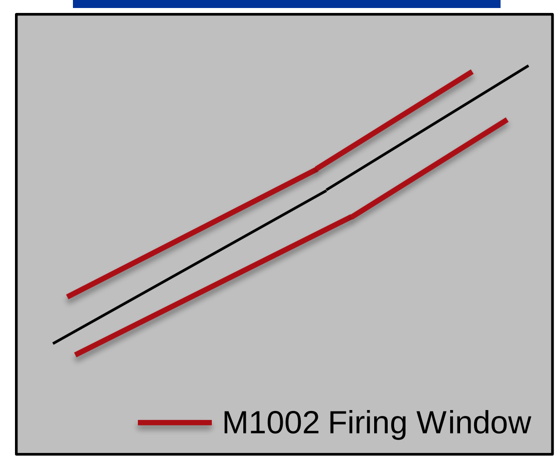

Original PAP8386

Alternate Path




Shift firing table to meet PAP8386 ballistics

Preferred Path



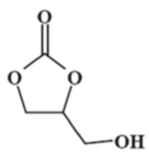

Novel inert plasticizer to manipulate propellant ballistics

# Preferred Path to M14 Replacement

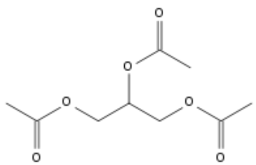


- **Replacing DEGDN in PAP8386**
  - Combination of NG and inert plasticizer to mimic ballistic potential of PAP8386
  - Inert plasticizers chosen based on literature as well as melting point, boiling point, density, and solubility

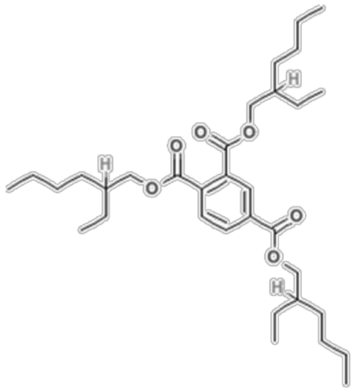
## Inert Plasticizers



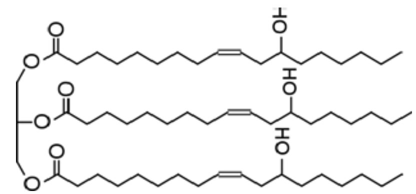
Glycerol Carbonate



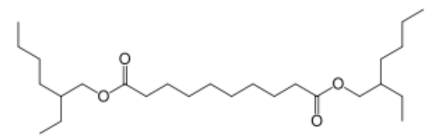
Triacetin



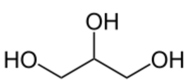
Trioctyl Trimellitate (TOTM)



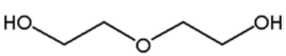
Castor Oil



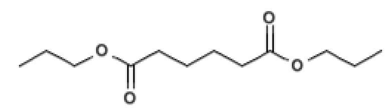
Dioctyl Sebacate (DOS)




Glycerol




Diethylene Glycol



Dipropyl Adipate (DnPA)

| Inert Plasticizer | Melting Point (°C) | Boiling Point (°C) | Density (g/cc) | Solubility in Water |
|---|---|---|---|---|
| Castor Oil | -14 | 313 | 0.958 | insoluble |
| Diethylene Glycol (DEG) | -10 | 245 | 1.118 | soluble |
| Di n-Propyl Adipate (DnPA) | -15 | 273 | 0.975 | insoluble |
| Dioctyl Sebacate (DOS) | -48 | 256 | 0.910 | insoluble |
| Glycerol | 18 | 290 | 1.261 | soluble |
| Glycerol Carbonate | -69 | 105 | 1.400 | 1-10% in water |
| Glycerol Triacetate (Triacetin) | -78 | 259 | 1.155 | 6% in water |
| Trioctyl trimellitate (TOTM) | -50 | 414 | 0.989 | insoluble |

# Preferred Path to M14 Replacement

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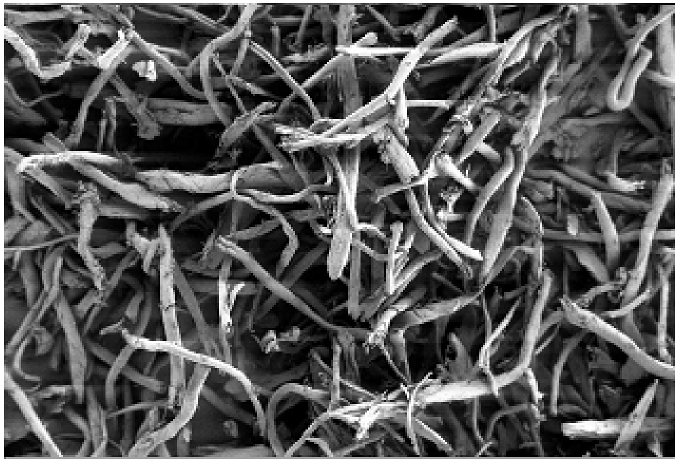
- **Replacing Lint NC in PAP8386**
  - Utilizing wood pulp NC for affordability and possible processing benefits
  - Various NC nitration combinations (influences processability and mechanical properties)



% Nitration (12.0 – 13.5)

# Evaluation 1 – Replacing DEGDN in PAP8386



**11 Formulations (NG and inert plasticizer to replace DEGDN)**

- 7 processed, 4 did not process
- Formulated to PAP8386 ballistic potential
- Formulated toward a desired plasticizer/binder ratio
- High level of success processing various types of nitrocellulose
  - Wood pulp and cotton linters (12.0 – 13.5 %N)
- Two plasticizers processed well
- Four plasticizers yielded unprocessable propellant sheets
- Completed closed bomb analysis on sheetstock of successful formulations

**Successfully processed alternative to PAP8386 propellant**

# M14 and PAP8386 Propellant Burn Rate Behavior

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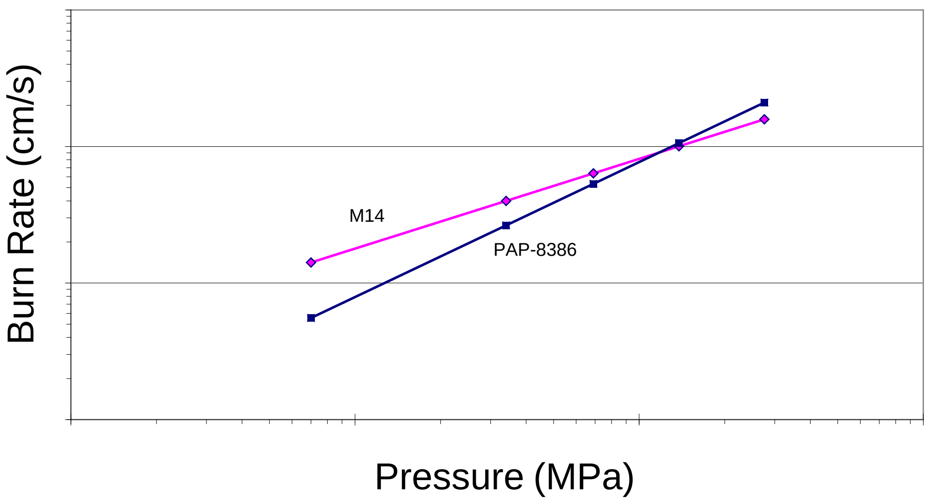
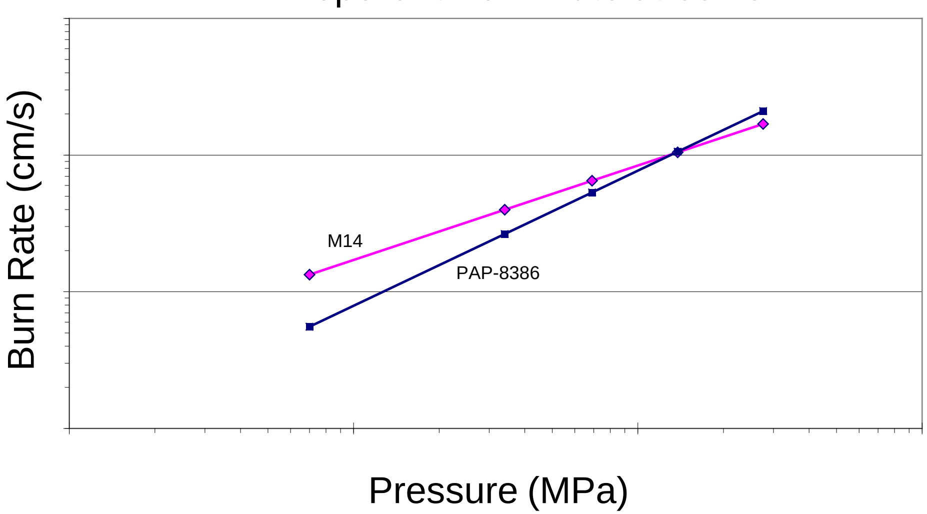
Propellant Burn Rate at 21 C



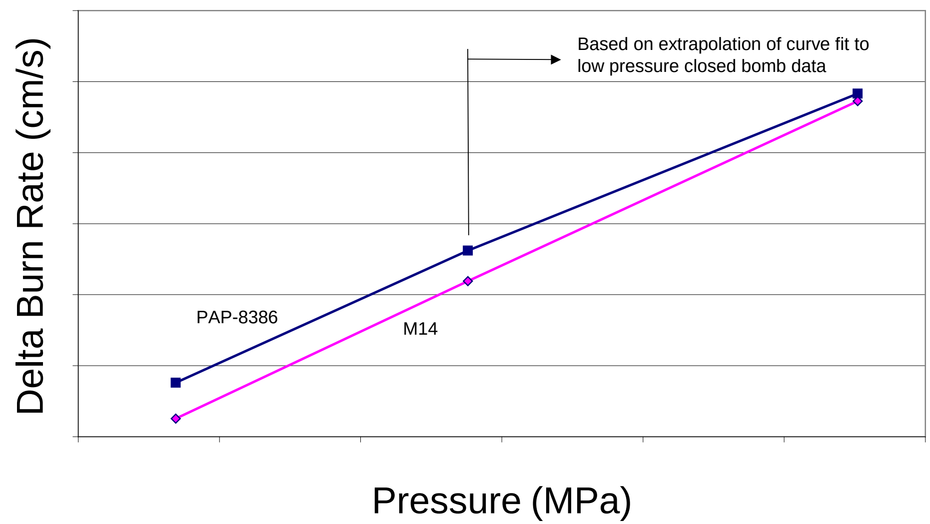

Propellant Burn Rate at 63 C




## PAP-8386 burn rate pressure coefficient (B) higher than M14

$$b_r = B(P)^n$$

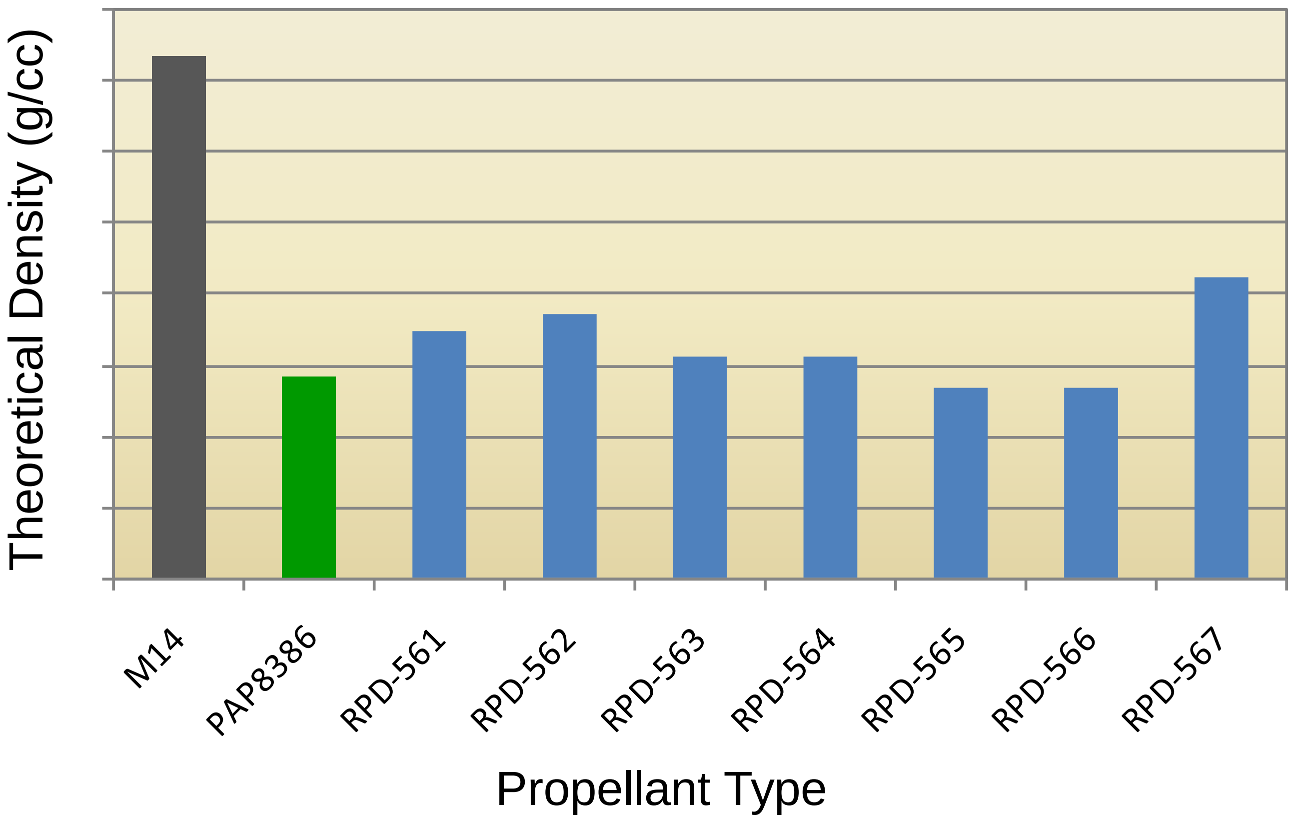
(Hot – Ambient) Burn Rates




## Cold M14 Data not available

# Theoretical Density of M14 Replacement Propellants

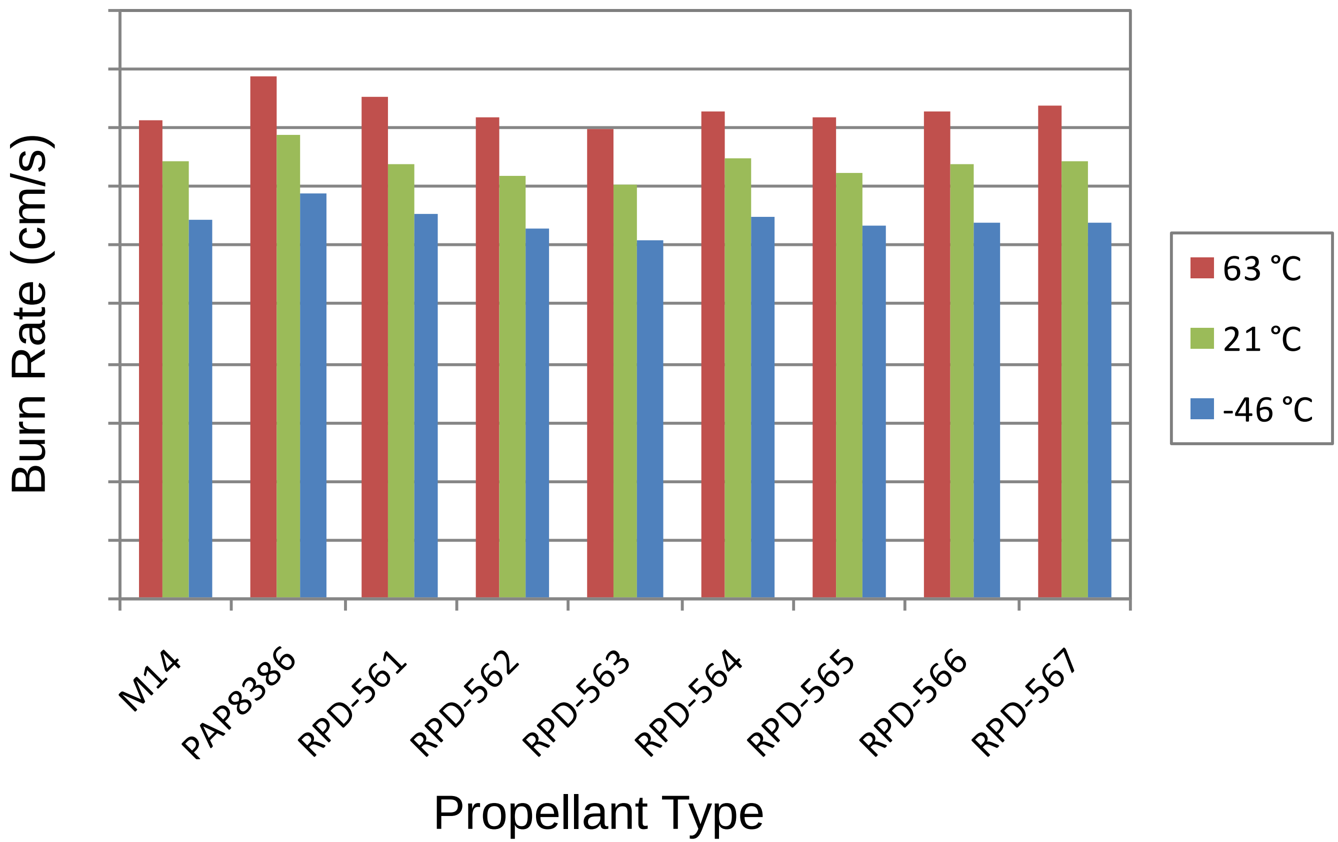




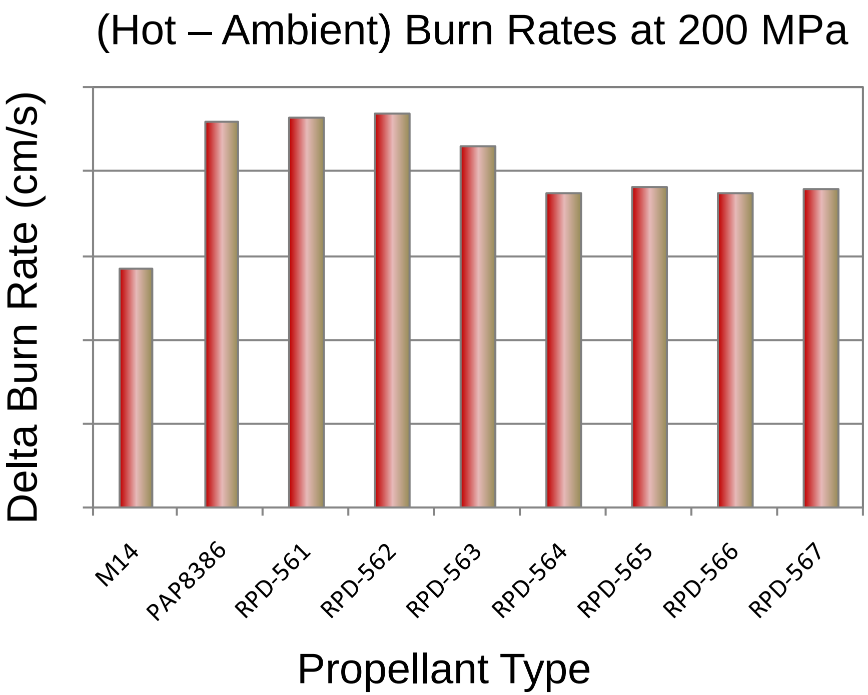

- Solventless propellants exhibit lower theoretical densities
  - Most inert and energetic plasticizers are less dense than Nitrocellulose
  - More plasticizers are necessary to process solventless propellant

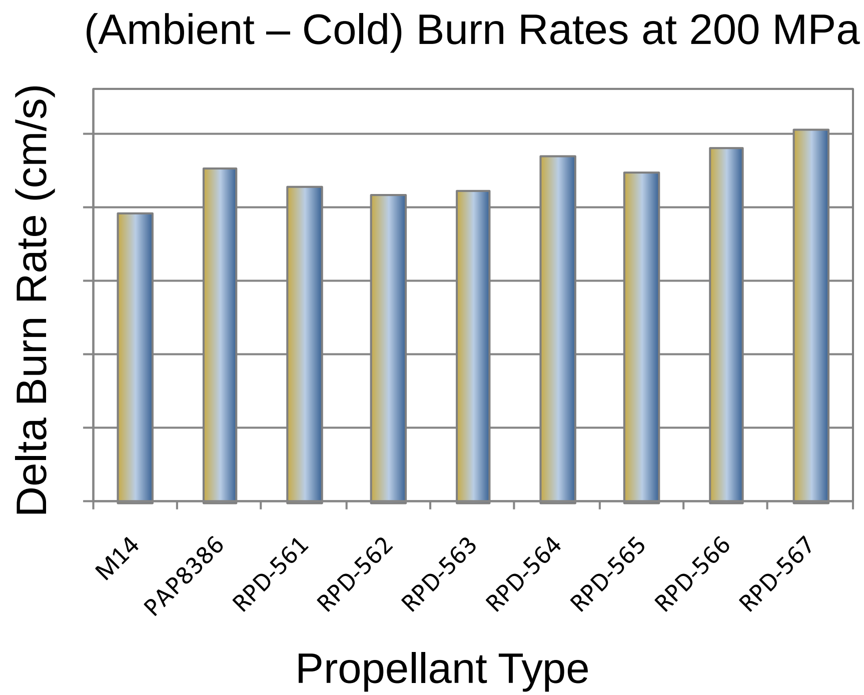
# Propellant Burn Rate at 200 MPa






- RPD-561 through 567 have similar burn rates to PAP8386
  - Changes to the final grain geometry would be necessary to reach or exceed PAP8386 burn rates
  - 120 mm gun data is essential in determining the optimal propellant formulation




- Temperature sensitivities are similar between all propellants
  - RPD-561 through 567 could be feasible PAP8386 replacements

**Change in burn rates between temperatures is higher than M14 propellant**

# Evaluation 2 – Replacing DEGDN in PAP8386



**<u>14 Formulations (NG and inert plasticizer to replace DEGDN)</u>**

- Formulated to PAP8386 ballistic potential
- Examined processing NC at various nitration levels (11.95-13.15 %N)
- Formulated with a fixed plasticizer/binder ratio
  - Lower ratio to aide processing of inert plasticizers
- 1 processed, 13 did not process
- One plasticizer processed acceptable propellant sheets
- Five plasticizers yielded unprocessable propellant sheets
- Awaiting closed bomb analysis on sheetstock of successful formulation

**Plasticizer/binder ratio plays a significant role during processing**

# Conclusions and Future Work

## Conclusions

- Examined various novel inert plasticizers for solventless propellant development
- Successfully developed a cost effective version of PAP8386
  - Closed bomb results indicate propellants with similar burn rate characteristics

## Technical Risks

- Meeting M1002 minimum velocity at -32 C
- Exceeding M1002 pressure requirement at 63 C
- High pressure cold due to propellant breakup

## Future Work

- Perform additional evaluations
- Downselect two propellants for ballistic testing
- Charge establishment and charge verification
- Initial ballistic evaluation of M865 and M1002 rounds
- Propellant web optimization study
- Ballistic test of final propellant at temperature extremes

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# QUESTIONS???

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