GENERAL DYNAMICS
Strength on Your Side

Medium and Large Caliber Propellant Solutions

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GENERAL DYNAMICS
Ordnance and Tactical Systems

GD-OTS Propellant Capabilities

GD-OTS
St. Marks Powder

Producing Propellant
Since 1970
1974 Acres,
# of Buildings - 137
# of Employees - 350

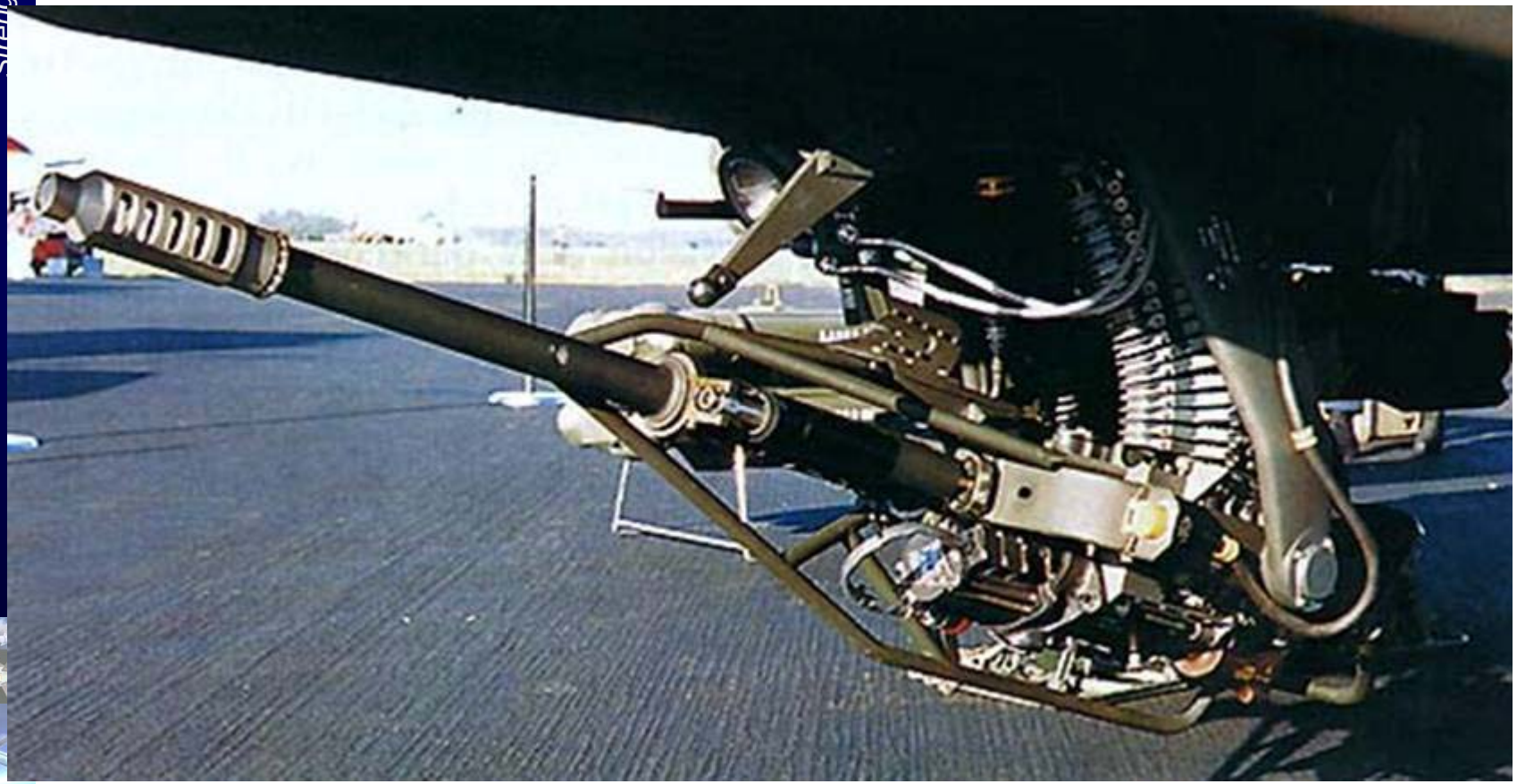
GD-OTS Canada
Valleyfield

Producing Propellant
Since 1941
1112 Acres,
# of Buildings – 180
# of Employees - 420

Medium and Large Caliber Propellant Solutions

- **St. Marks Powder HYBRID Propellant for 30mm Lightweight Ammunition**
- **St. Marks Powder and Valleyfield Extruded/BALL POWDER® Propellant Mixed Charge Concept**
- **Valleyfield M-14 Replacement Effort for 120mm Tank Trainer Ammunition**

The Army has experienced numerous M230 Chain Guns failures with 30mm M789 HEDP ammunition when exposed to hot temperatures over extended periods of time



The Apache's 30 mm x 113 automatic M230 chain gun

30mm Lightweight Improved Hot Temperature Storage

Overview

- GD-OTS St. Marks Powder is currently developing a single perf, HYBRID propellant to replace WC 855 BALL POWDER® Propellant to with improved hot temperature storage properties (ballistic stability)
  - Meets interior ballistic specifications
  - Meets fire control goals
  - Expected to have very good barrel wear/life

HYBRID Propellant for 30mm M788/M789

The State-of-the-art in Propellant Technology for Small, Medium and Large Caliber Ammunition

Ultimate ballistic efficiency achieved by combining perforated geometry with burn rate modifiers (deterrents)

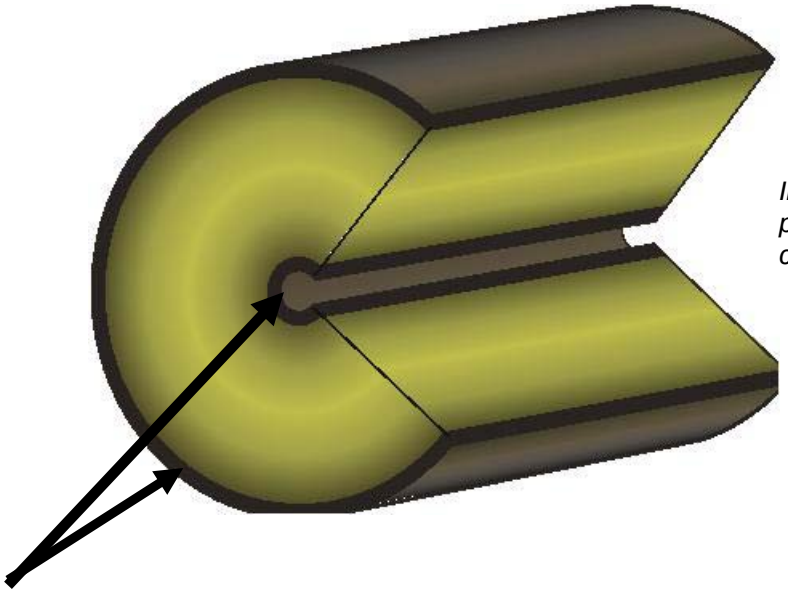


Illustration of a propellant grain cross section

Deterrent Layer - applied to tailor the burn rate for specific applications to optimize ballistic efficiency

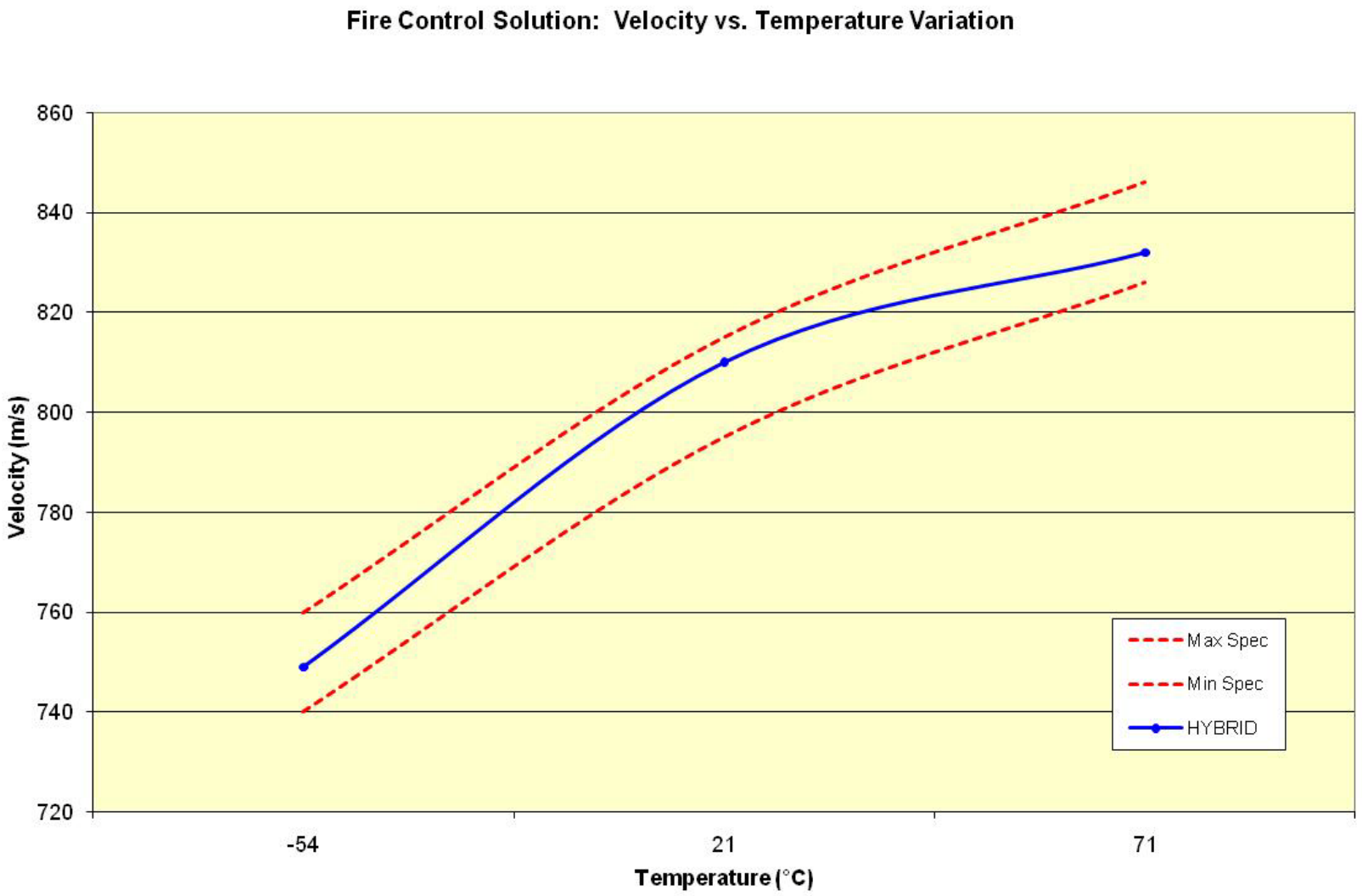
Deterrent Layer – Lowers overall flame temperatures and provides a relatively cool burning outer layer

Addresses Needs for 30mm M788/M789 Ammunition

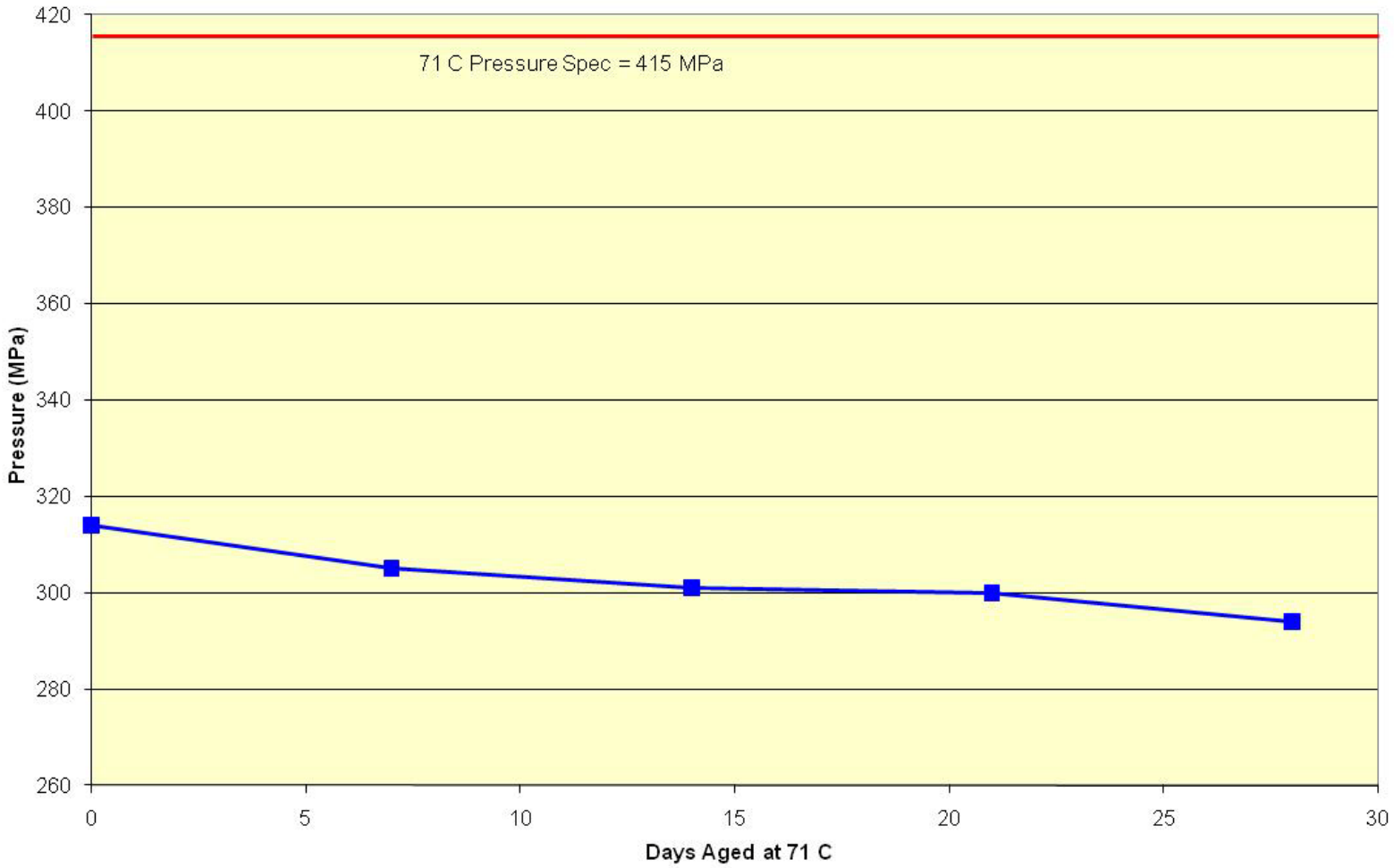
- **Superior Robustness to Hot Temperature Exposure**
  - Excellent High Temperature Storage Results
  - No increase in peak pressure after conditioning
    - Dual Stabilizers used, including Akardite II for long shelf life

- **Current off-the Shelf Product ("Drop-In Replacement")**
  - Commercial variant of SHP 831 already in production
  - Economical - using conventional processes and low cost materials
  - Excellent temperature sensitivity
  - Excellent ignition properties
  - Excellent IM properties

30mm Lightweight HYBRID Data



HYBRID Propellant Operating Pressures in LW 30mm after Extended High Temperature Exposure at 71°C (160°F)



Improved Propellant: HYBRID SHP 831

- HYBRID SHP 831 propellant represents an economical state-of-the-art propellant
- Currently in production for commercial applications
  - Loading rate between BALL POWDER® and Extruded Propellants (little if any impact on ammunition loading equipment or capacity)
- St. Marks Powder HYBRID propellants are domestically produced in existing production facilities

St. Marks Powder and Valleyfield Extruded/BALL POWDER® Propellant Mixed Charge Concept

High Performance Propellant Technology

High Loading Density
+ Ballistic Efficiency

= High Performance

The ability to achieve higher charge weights combined with the appropriate burn progressivity (ballistic efficiency) will yield higher performance capabilities

Mixed Propellant Charge - Objective

- Valleyfield and St. Marks Powder Objective: Demonstrate this concept in ammunition to achieve improved ballistic performance
  - Chose 30mm GAU-8/A PGU-15 /B TP ammunition as a Baseline
  - In 2009, Valleyfield started with a 7-Perf, surface deterred, extruded propellant
  - Blended in a small diameter, surface deterred, BALL POWDER® propellant
  - Loaded with vibration

Achieved 17% charge weight increase with excellent ballistic efficiency, very good standard deviations and low flame temperature

Mixed Propellant Charge

- In 2010, Valleyfield tested a 19-Perf, surface deterred, extruded propellant
  - Blended in a small diameter, surface deterred, BALL POWDER® propellant
  - Loaded with vibration

Achieved 19% charge weight increase

Mixed Charge Propellant Concept

7-Perf Extruded and
BALL POWDER® Propellant

19-Perf Extruded and
BALL POWDER® Propellant

30mm Ballistic Results - Projected

Baseline @ 145 grams = 3,340 fps

1st Iteration Mixed Charge @ 170 grams = 3,623 fps

Represents an 18% increase in Kinetic Energy +283 fps

Planned Iteration Mixed Charge @ 188 grams = 3,730 fps

Represents a 25% increase in Kinetic Energy +390 fps

Mixed Propellant Charge – Future Work

Future Work

- Maximize charge weights
  - *Geometry and Loading Studies*
- Maximize ballistic efficiency with deterrent technology
- Optimize standard deviations and temperature sensitivity
  - *Propellant chemistry (Compatibility)*
  - *Ignition system*
- Ensure excellent long-term, hot temperature ballistic storage
- Ensure excellent IM properties

Valleyfield M-14 Replacement Effort for 120mm Tank Trainer Ammunition

Introduction

- The main processing solvent of M14, diethyl ether, has a strong affinity for NC.
- Diethyl ether is also known for its high flammability
- A number of tank fires in training exercises have put in question the use of M14 propellant in 120mm training ammunition.

Residual solvent reduction

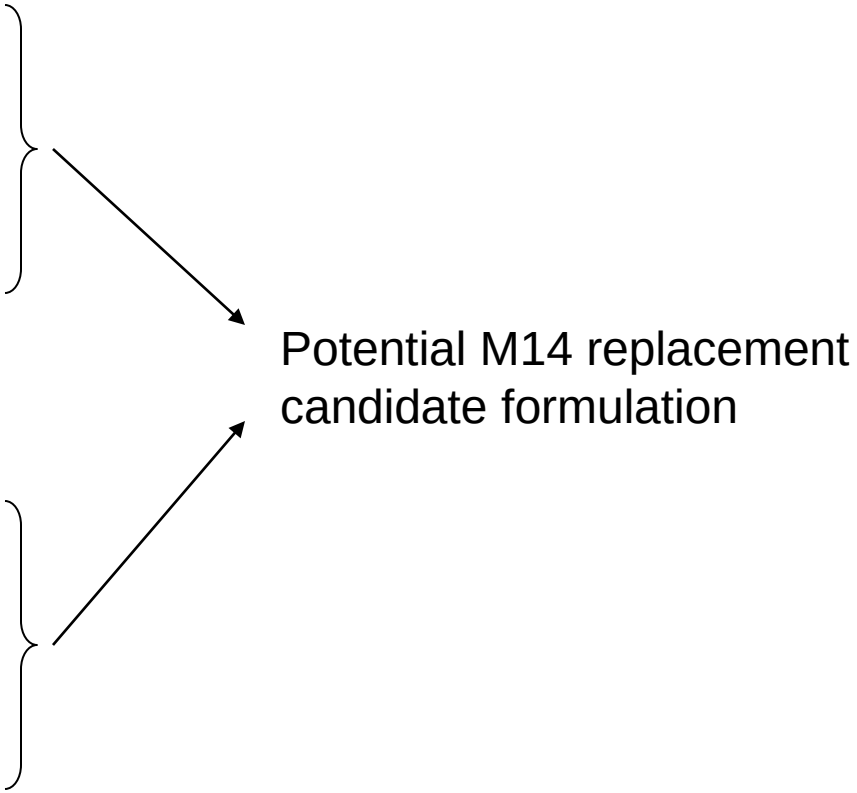
Double base formulation

Easier solvent removal

NG free formulation

Better insensitivity

Lower flame temperature



TMDB formulation

- “T”EGDN
- “M”odified
- “D”ouble
- “B”ase

An NC based formulation that is plasticized with tri-ethylene glycol dinitrate (TEGDN)

TEGDN

- Extremely insensitive (impact sensitivity almost 100 times less then DEGDN).
- Better thermal stability then NG and DEGDN.
- Not a vasodilatator.
- Better gelatinizing agent to NC then NG.
- Less mobile then DEGDN and NG.

Meyer R, Köhler J, Homburg A, Explosives, 5th Revised Edition, Wiley-VCH, 2002.
Urbanski T, Chemistry and Technology of Explosives, Pergamon Press, 1984.
Fedoroff B T, Sheffield O E, Kaye S M, Encyclopedia of Explosives and Related Items, Picatinny Arsenal.
Lewis R J, SAX's Dangerous Properties of Industrial Chemicals, 9th Edition, Van Nostrand Reinhold, 1996.

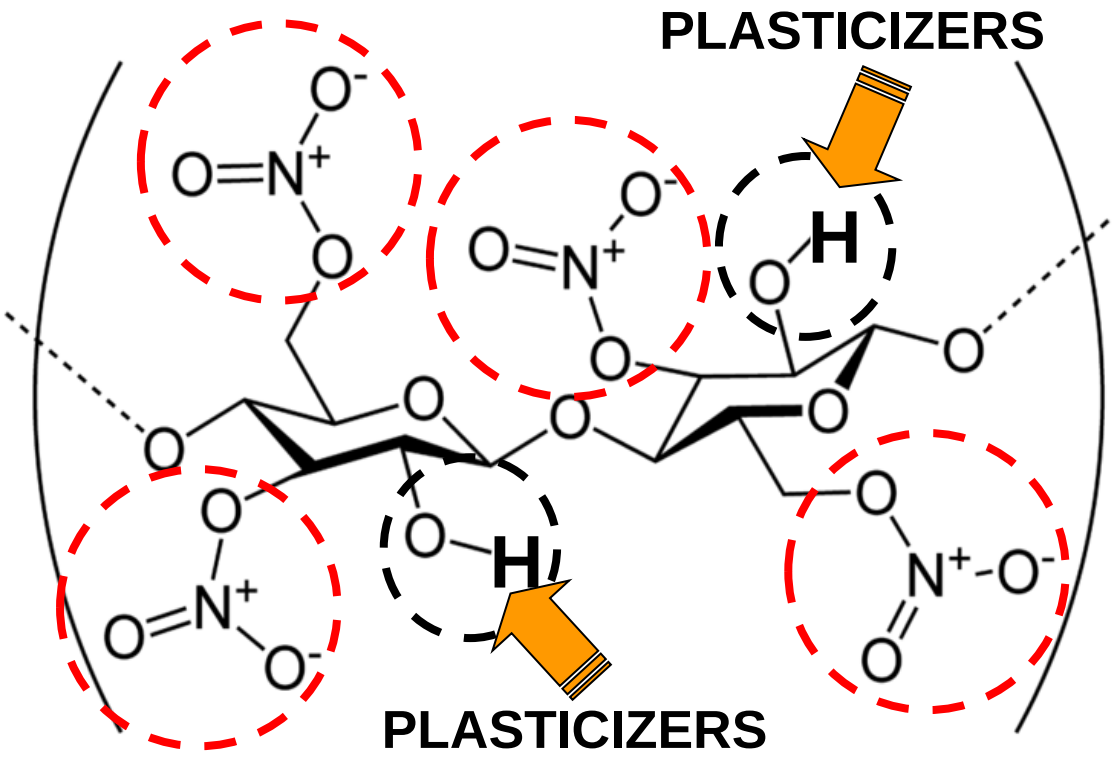
Processing solvents

- A mixture of acetone and ethanol is used in the manufacturing process. These solvents are much safer than the usual diethyl ether used in M14 manufacturing.

Characteristics	Diethyl ether	Acetone	Ethyl Acetate
LEL, %V/V	1.9	2.5	2.2
Explosivity range (UEL-LEL), %V/V	34.1	10.3	9.3
Flash point, °F	-49	0	24.8
Vapour pressure, mm Hg	440	180	75

- Given that the TMDB formulation contains 30% of plasticizer, the amount of required solvent in the process is reduced by 50% to 70% (10-15% at extrusion instead of 30-35% for M14).

Residual solvents



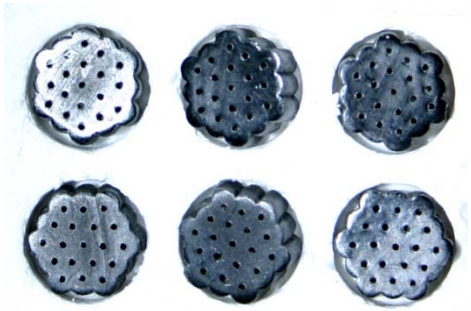
CH_3-CH_2-O-H

CH_3-CH_2-O-CH_2-CH_3

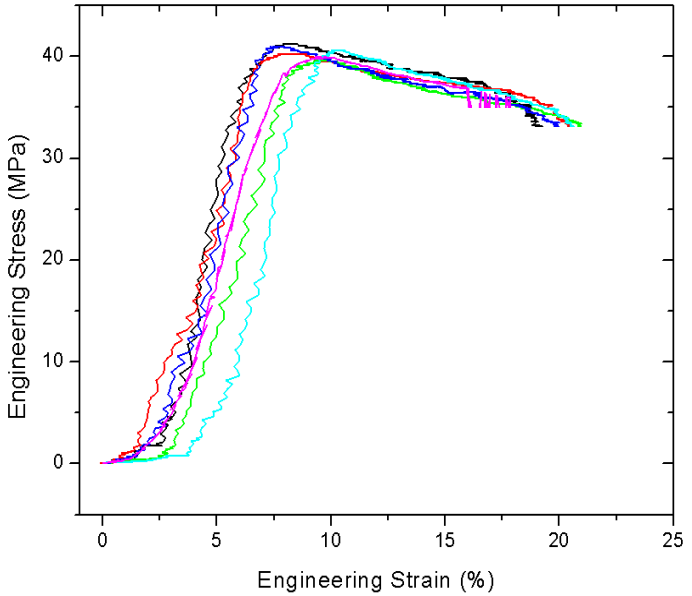
With TMDB propellant, the hydrophobic plasticizer (TEGDN) will block the hydroxyl groups and drive off the solvents

Mechanical properties

Grain Type	Compressive Modulus
	(Gpa)
TMDB	**1.01 ± 0.18**
JA2	0.722
M14	2.79
M30A2	1.638
XM39	3.07 ± 1.27



Mechanical properties are similar to JA2



Insensitivity testing

- A shape charge jet attack test yielded a Type III reaction on a 105mm tank cartridge with 9.9 Lb of TMDB propellant

- An 84mm (Carl Gustav) shape charge jet and a brass cartridge case were used

TMDB configurations

19 Perforations hexagonal rosette

1 Perforation cylindrical

7 Perforations cylindrical

Surface moderation has also been applied to these geometries when necessary in order to increase the ballistic efficiency.

Ballistic testing

- All testing was done as part of the original M14 replacement effort between 2005 and 2007.
- TMDB has been tested successfully in the 120mm M865 tank cartridge.
- In the case of the 120mm M1002, the right temperature slope was obtained but the geometry has to be optimized in order to decrease the pressures.

Future efforts

- As part of the current M14 replacement program, TMDB will be used as a potential solution.
- The goal is to confirm the previous M865 success and lower the pressures in the M1002 application through a change of geometry.
- All candidates shall have a residual solvent level lower then 0.1%.
- All testing for the first phase of this program is scheduled to be completed by August 2010.