



# InFuse™ Nitrocellulose: Production, Propellant and Potential

8<sup>th</sup> Nitrocellulose Symposium  
5 -7 June 2018 - Bergerac



# Outline



- History of InFuse™
- Production of InFuse™ Nitrocellulose
- Characterization
- Production of InFuse™ Propellant
- Ballistics
- Applications



“Methods of preparing nitrocellulose based propellants and propellants made therefrom” W.J. Worrell, B. R. Vaughan, J. D. Archambault, M. Fils-Aime; U.S. Patents 9,393,164 and 9,885,550.

## Utilize commercially available, pre-shaped cellulose

- Simplify propellant processing/manufacturing
- Cost – Reduce labor, decrease capital/equipment requirements
- Safety – Less handling/processing of energetic materials
- Environmental – Reduce/eliminate organic solvent usage (VOC) and waste

## Access to multiple geometries and configurations

- Spherical, cylindrical, perforated, complex grain designs (additive manufacturing)

## Multiple Pre-shaped Cellulose and Cellulose Derivatives Options

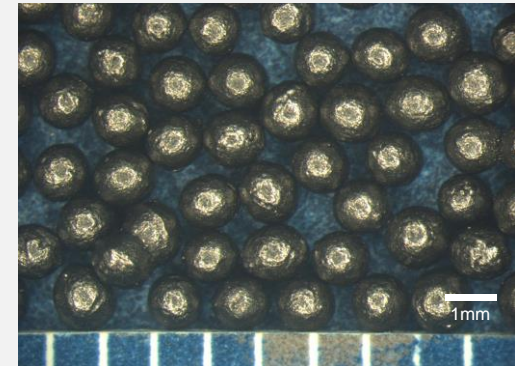
- Excellent control of raw ingredients
  - Particle size, moisture, density
- Range of attainable energies



Cellulose spheres



InFuse™ NC spheres



Coated InFuse™ DB propellant

# NC Production Comparison



## CONVENTIONAL NC PROCESS

CELLULOSE  
PREP.

NITRATION

STABILIZATION

REFINING

POACHING  
& BLENDING

ALCOHOL DEHY.  
& PACKOUT



CELLULOSE

ACID

NITRATION

STABILIZATION

PACKOUT

## INFUSE™ NC PROCESS

## INFUSE™ NC PROCESS

- Pre-shaped cellulose
- Simplify stabilization
- Fewer process steps

InFuse™ NC Technology Streamlines NC Manufacture

# InFuse™ Characterization



## Nitrogen Levels

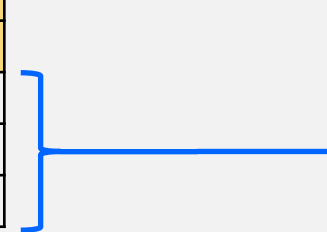
- All Grades of NC achieved
- Multiple particle sizes
  - 25 μm – 1 mm

MIL-DTL-244B NC requirements		InFuse™ NC data		
<i>Conventional NC</i>	<i>% Nitrogen</i>	<i>% Nitrogen</i>	<i>Shape</i>	<i>Avg. size (μm)</i>
Grade A	12.60 ± 0.15	12.74	Granular	65
Grade B	13.35 (min.)	13.47	Spherical	350
Grade C	13.25 ± 0.05	13.25	Granular	150
Grade D	12.25 ± 0.05	12.29	Spherical	250
Grade E	12.00 ± 0.10	12.04	Spherical	350
Grade F	11.30 – 11.80	11.84	Spherical	500

Sample	ABL impact (cm)	ABL friction (lb @ ft/s)
Standard NC (Grade B)	6.9	74 @ 8
InFuse™ NC (100 μm, Grade B)	120 ←	75 @ 8
Perforated single base propellant	13	60 @ 8
InFuse™ single base propellant	100 ←	175 @ 8 ←
Ball propellant (8% NG)	13	220 @ 8
InFuse™ propellant (10% NG)	21 ←	170 @ 8
Baseline lacquer (0% InFuse™ NC)	11	128 @ 3
RLSD-661 (3% InFuse™ NC)	17	310 @ 3
RLSD-665 (5% InFuse™ NC)	26	230 @ 3

## Small scale sensitivity benefit

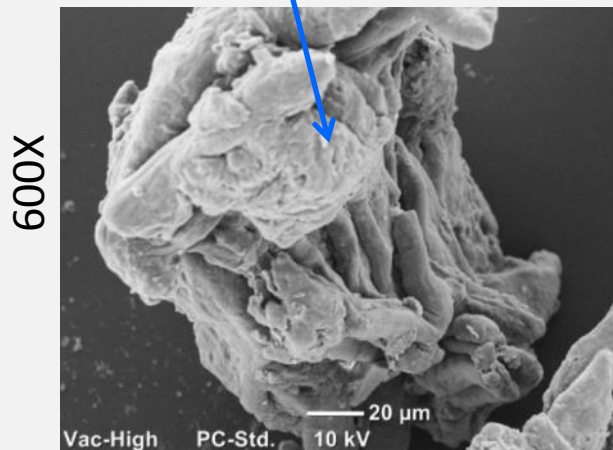
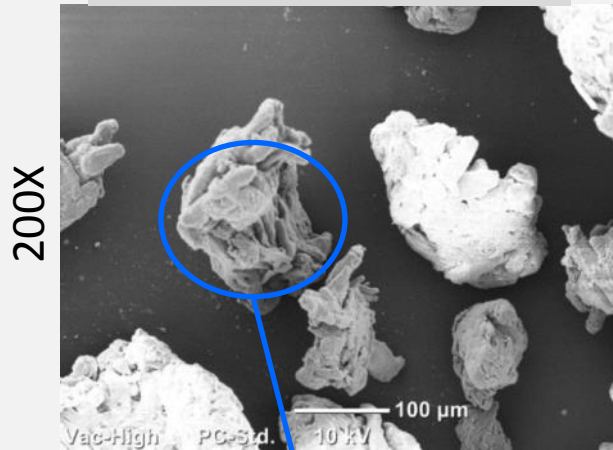
- Improved impact and friction
- Carryover into formulations
- System level IM benefits?



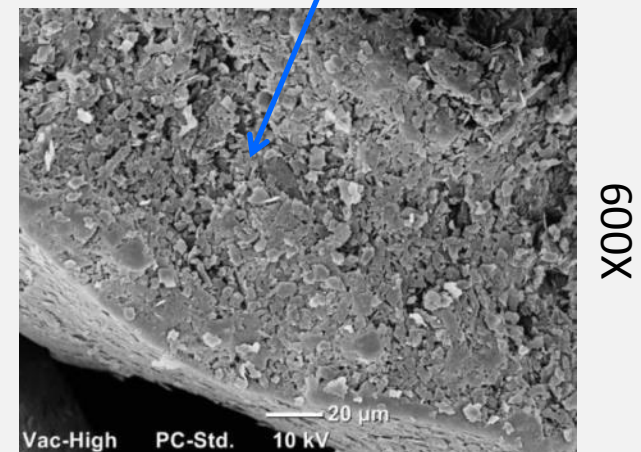
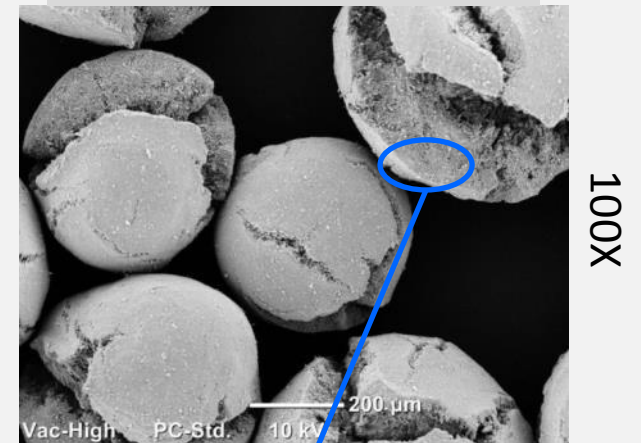
## Microstructure

- InFuse™ NC – very fine particulate visible at high magnification
- Shortened or no fibrous structures observed

### Granular InFuse™ NC



### Spherical InFuse™ NC





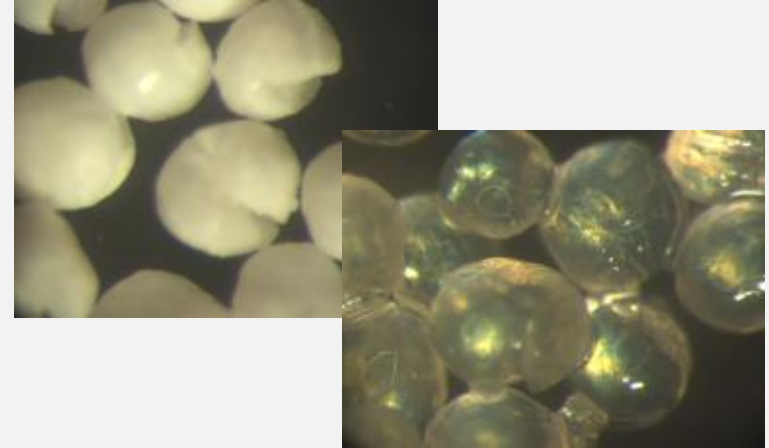
# InFuse™ Characterization



## Plasticizers

- InFuse™ compatible with all common plasticizers
- Can absorb up to 50 wt% plasticizer with minimal swelling
  - InFuse™ NC has a very strong affinity for plasticizer

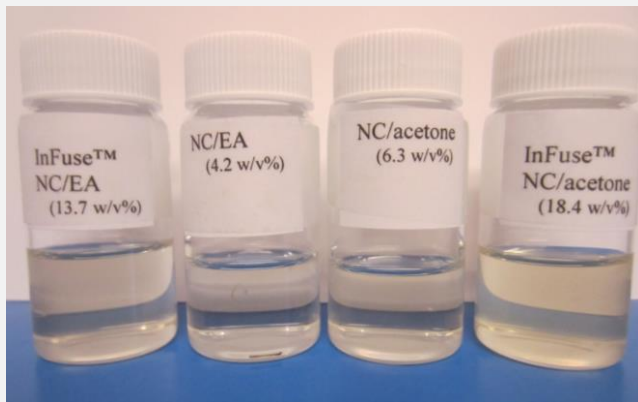
Grade B InFuse™ NC



Plasticized Grade B InFuse™ NC

## Solubility

- InFuse™ NC significantly more soluble than conventional NC
  - Pourable lacquers contain 3X more InFuse™ NC than conventional NC
  - InFuse™ NC lacquers are lower viscosity



Falling ball viscosity*- Grade B nitrocellulose lacquers			
Sample	Solvent	Concentration (w/v%)	Time (sec.)
Conventional NC	acetone	6.3	8.8
InFuse™ NC	acetone	18.4	3.2
Conventional NC	ethyl acetate	4.2	7.4
InFuse™ NC	ethyl acetate	13.7	2.7

\* Standard 8mm steel ball, timed through a column of NC lacquer 8 cm (L) x 1.3 cm (D) at 20°C

# Propellant Production



## INFUSE™ PROPELLANT PROCESS



- Add stabilizer (ethanol process)
- Refortify and reuse stabilizer solution
  - Recover/recycle ethanol
  
- Add plasticizer (water slurry process)
- Optionally: Add deterrent
  
- Graphite coating (wet or dry glaze)





# Propellant Production



## U.S. DOT Shipping Classification obtained for InFuse™ Single-base Propellant

- InFuse™ Granular Propellant (1.3C)
- Classified as smokeless powder, UN0161

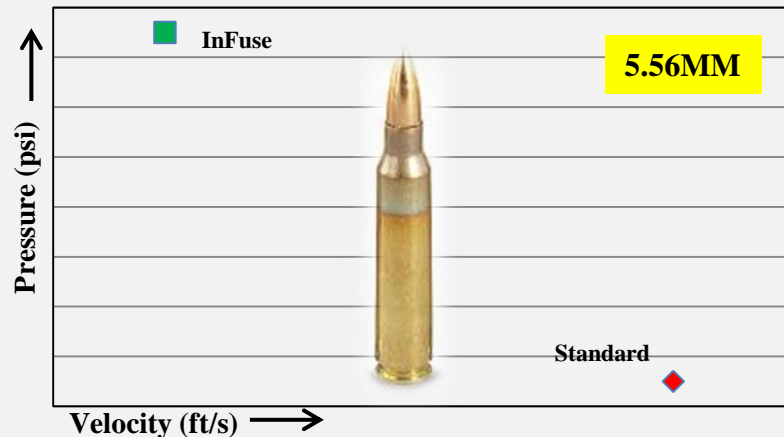
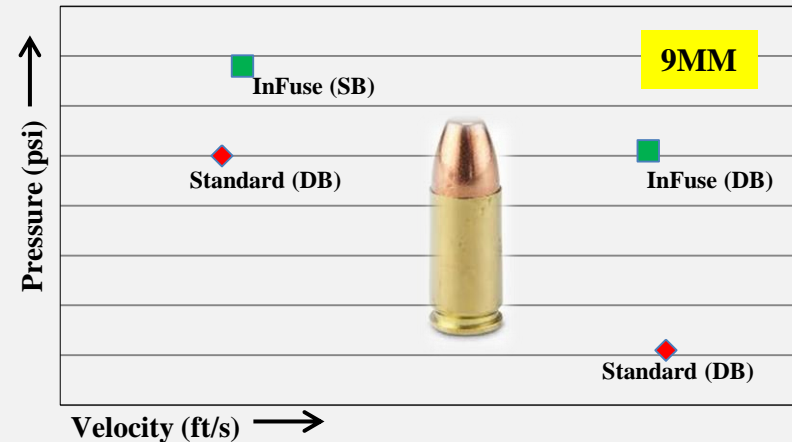
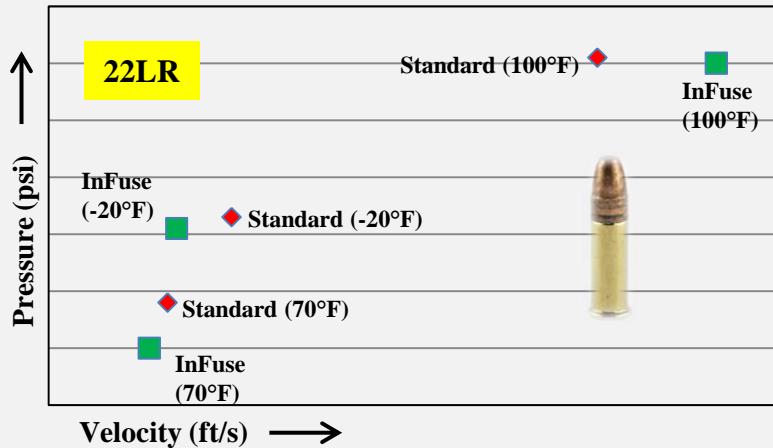


# Ballistic Results



## Good ballistic performance in multiple small calibers

- Rimfire (22LR) – Good performance at cold, ambient, and hot temperatures
- Centerfire (9mm, 5.56mm) – Reasonable ballistic match with standards
  - On-going deterrent work to improve relative vivacity of InFuse™ propellants



## Rifle/Handgun/Shotgun

- Rimfire
- Centerfire
- Commercial (Sporting)
- Military (5.56/7.62/50 cal/medium cal)



## Others

- Higher performance min. smoke rocket propellants
- Fasteners (construction)
- Black Powder replacement
- PNC alternative
- Primers
- Additive manufacturing (3D printing)
- Triple base gun propellant
- Tissue embedding (histology)



# Contributors



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