Processing Benefits of Resonance Acoustic Mixing on High Performance Propellants and Explosives

Dr. Andrew Nelson and Tara Cross

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NAVAIR

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Outline

- RAM Facilities and Set-up at China Lake
- Initial RAM Energetics Evaluation
- Propellant Mixed on RAM
- Explosive Mixed on RAM

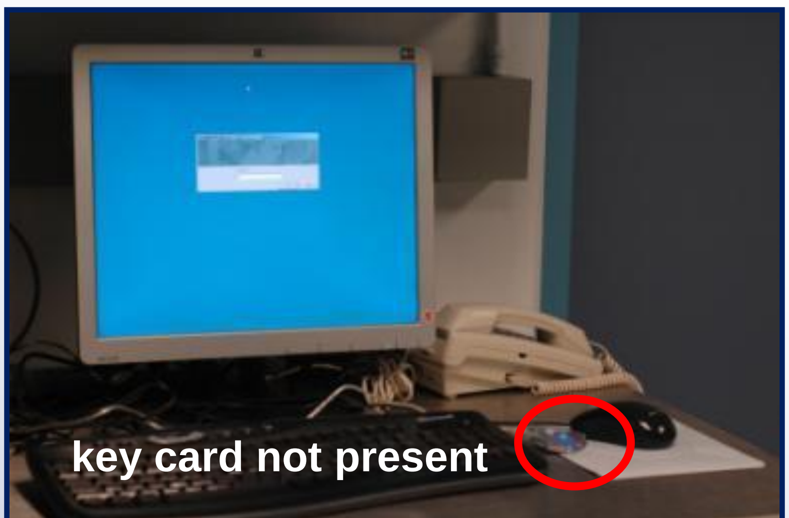
LabRAM

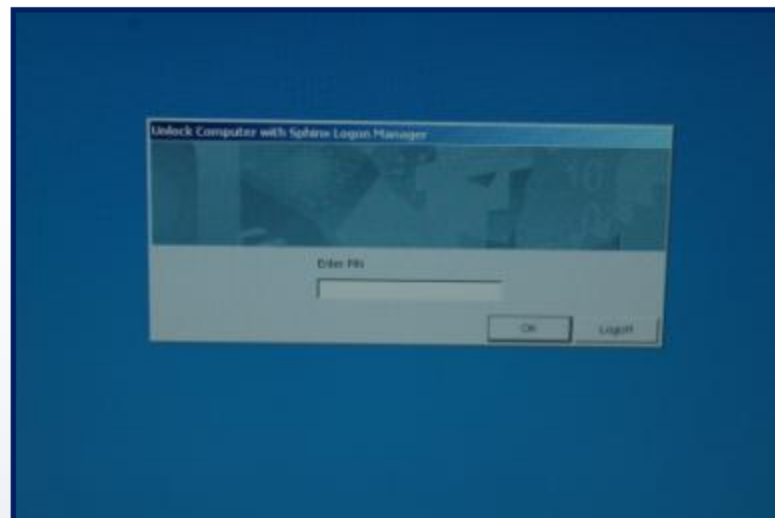
Resonant Acoustic Mixing of Energetic Materials at China Lake

Remote Operation

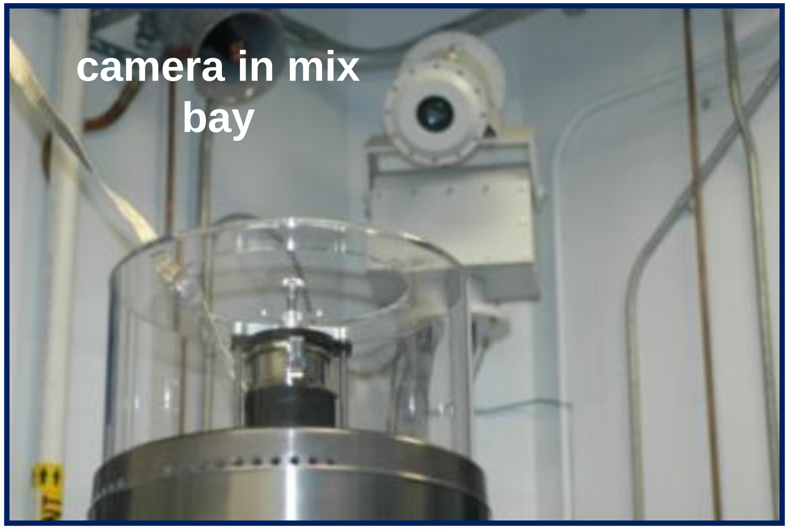
Distribution Statement A: Approved for Public Release

Computer Key Card Lockout





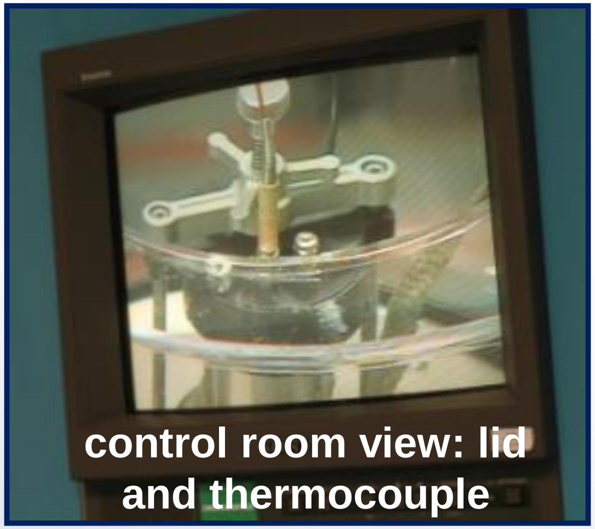
Remote Monitoring of Live Mix



camera in mix bay

control room view: zoomed out

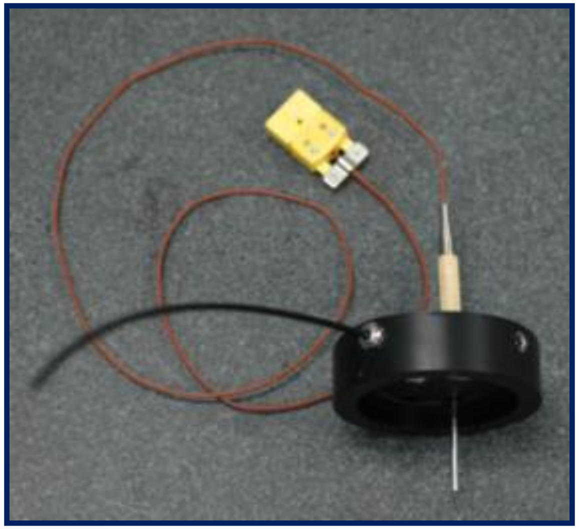
control room view: zooming in

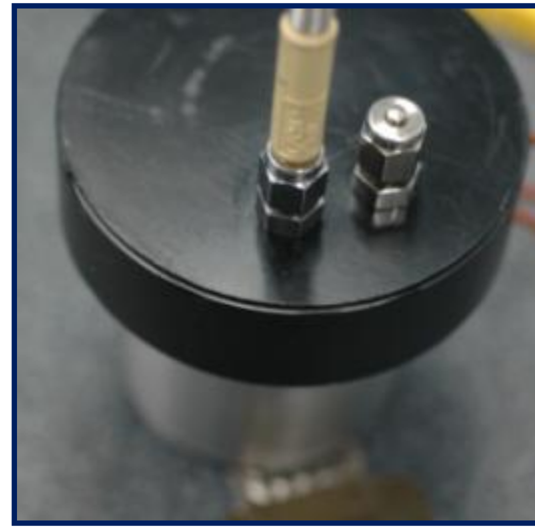


control room view: lid and thermocouple

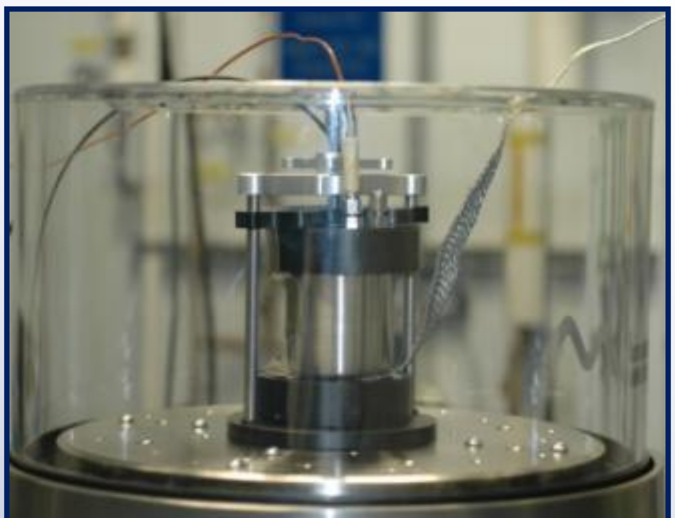
control room view: vacuum gage

Remote Temperature Monitoring

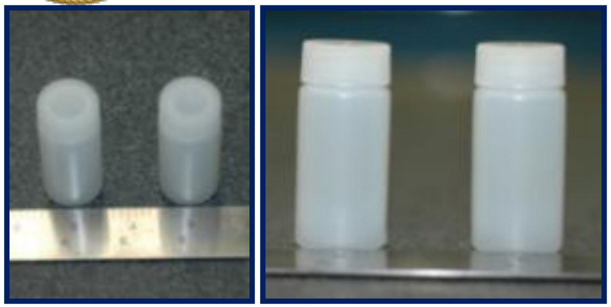




Thermocouple lid designed by Resodyn Acoustic Mixers, Inc.



General Mix Vessel Types



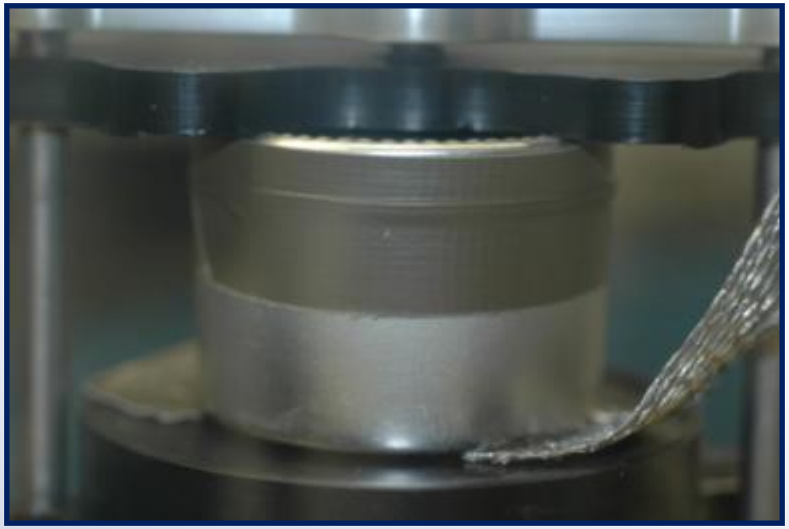
1- to 5-grams

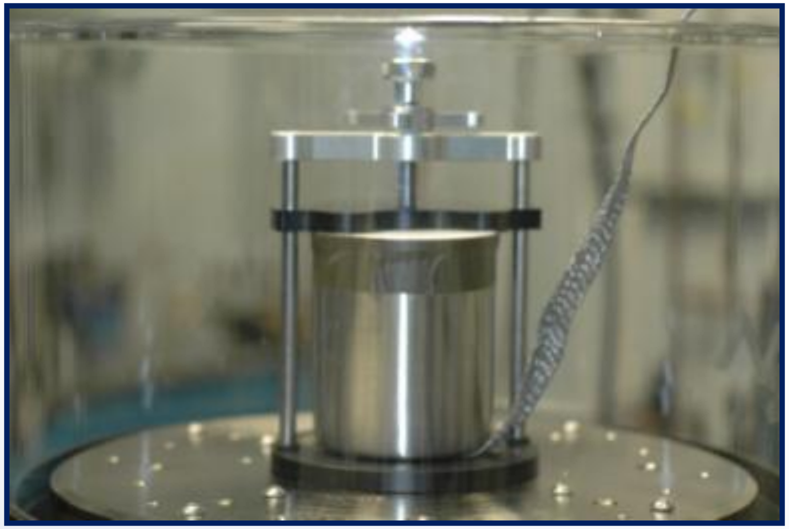
5- to 150-grams

25- to 400-grams

25- to 450-grams

Ground Mix Vessels



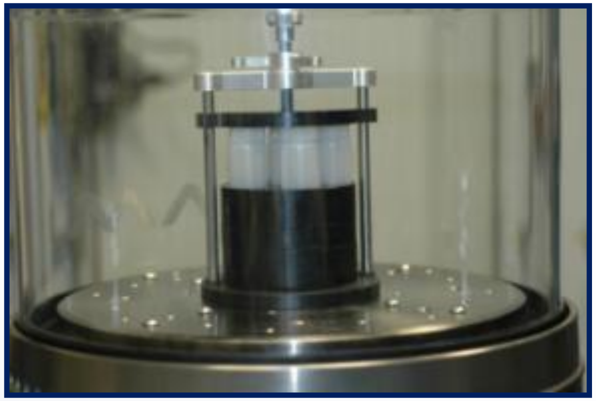


Mechanical grounding

Initial RAM Energetics Research

Initial Energetic Evaluation

- Selected Energetics
  - Polymers: GAP, PGN, PNO, BN-7
  - Plasticizers: BTTN, TMETN, TEGDN, BuNena
  - Nitramines: RDX, HMX, CL-20
- Developed mix matrix based on combinations of the energetic materials (1 from each group)
- Mix Vessel
  - Small 20-mL plastic vials



- Mix Sizes
  - 1-gram
  - 5-gram
- Mix Scheme
  - Ramped from 0% to 100% Intensity (I) using increments of 10% I
  - Held at 100% I for 10 minutes

Initial Energetic Evaluation

DSC Onsets for Energetics Mixed by Hand and RAM

Ingredients	HM DSC Onset (°C)	RAM DSC Onset (°C)	Difference (°C)
GAP-BTTN-RDX	206	203	3
GAP-BTTN-HMX	217	219	2
GAP-BTTN-CL20	202	204	2
PGN-BTTN-RDX	191	191	0
PGN-BTTN-HMX	183	186	3
PGN-BTTN-CL20	189	189	0
PNO-BTTN-RDX	184	189	5
PNO-BTTN-HMX	179	175	4
PNO-BTTN-CL20	185	185	0

- **DSC: ambient to 350° C by ramping 5° C/min.**

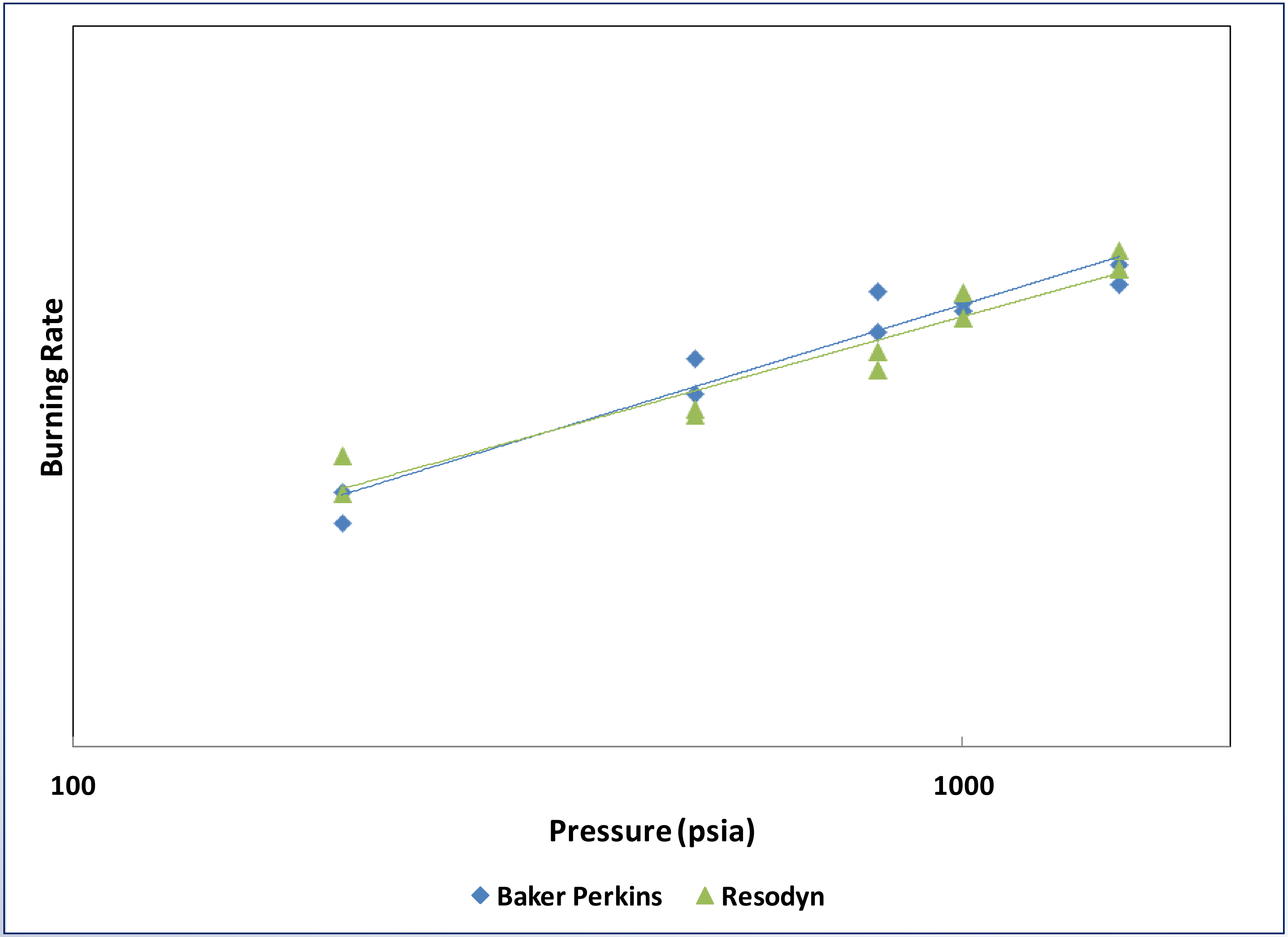
Resodyn Mixed Propellant

Propellant Study

- Compare the properties of a propellant formulation mixed on the Resodyn to the same formulation mixed on the Baker Perkins
  - End of Mix Viscosity
  - Ballistic Properties
  - Tensile Properties
- Formulation
  - HTCE, AP, Al
- RAM Mix Scheme
  - 125-gram mix
  - 4 mix periods, 40-50 G, total mix time 30 minutes, 78°F to 120°F
- Baker Perkins Mix Scheme
  - 125-gram mix
  - 7 mix periods, total mix time 100 minutes, 130°F
- End of Mix Viscosity
  - RAM: 21.5 kps at 95.9°F
  - BP: 7.5 kps at 120.7°F

Burning Rate Comparison

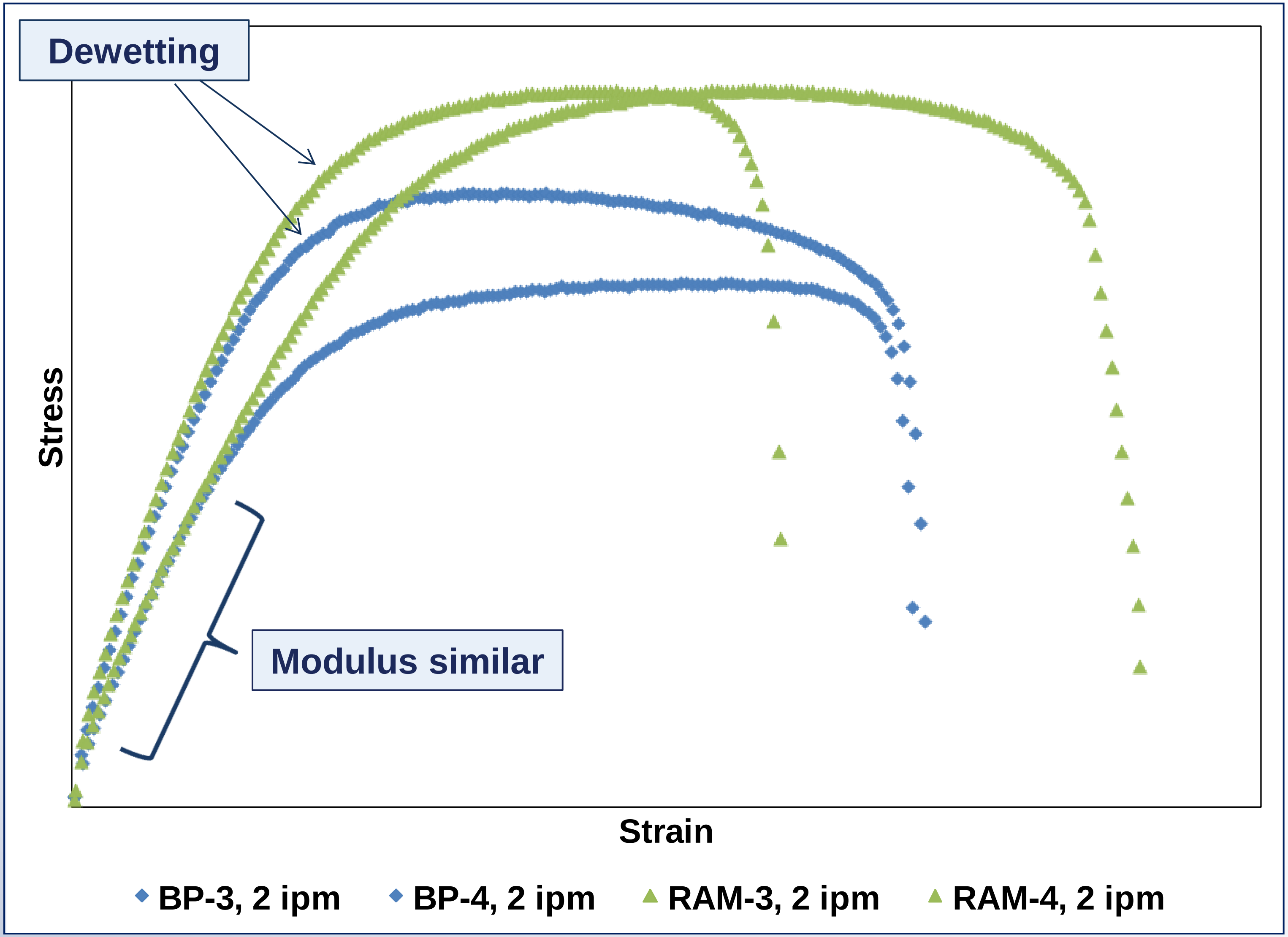
Burning Rates of Baker Perkins and Resodyn Mixed Propellants



- Low pressure window bomb data
- Burning Rates and Burning Rate Slope are similar

Tensile Comparison

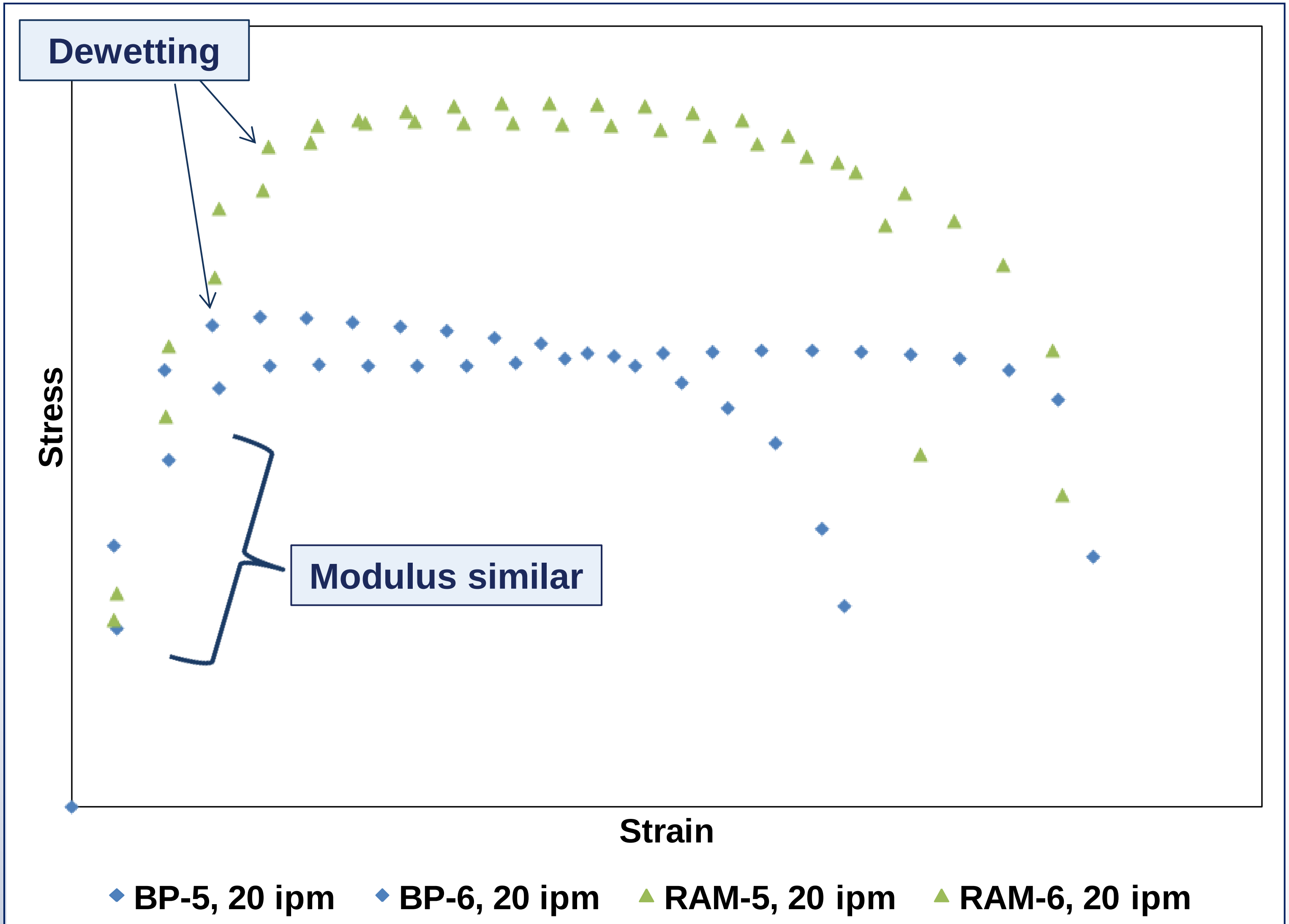
Tensile Properties of Baker Perkins and Resodyn Mixed Propellants



- Data from mini dogbones
- Pulled at RT and 2 in./min. cross-head speed
- RAM and BP samples show similar tensile properties
- RAM demonstrated slightly greater stress

Tensile Comparison

Tensile Properties of Baker Perkins and Resodyn Mixed Propellants



- Data from mini dogbones
- Evaluated at RT and 20 in./min. crosshead speed
- RAM and BP samples exhibit similar tensile properties
- RAM demonstrated greater stress

Resodyn Mixed Explosive

Explosive Formulation Study

- Purpose
  - Test the Resodyns ability to mix high viscosity materials by increasing the explosive particle surface area for a well known explosive formulation
    - Explosive particle surface area:
      - Baseline Mix: 0.021 m^2/g
      - Mix A: 0.165 m^2/g
      - Mix B: 1.65 m^2/g
- Motivation
  - Improve solids loading to obtain higher operational performance
  - Improve shock sensitivity for better IM performance
- Explosive Formulation
  - High solids filled polybutadiene binder

Mix A (0.165m^2/g)

Step 1: All ingredients; Mixed at 100% intensity for 60 min.; Material Temperature -- 128° F (2 min. after mixing is complete)

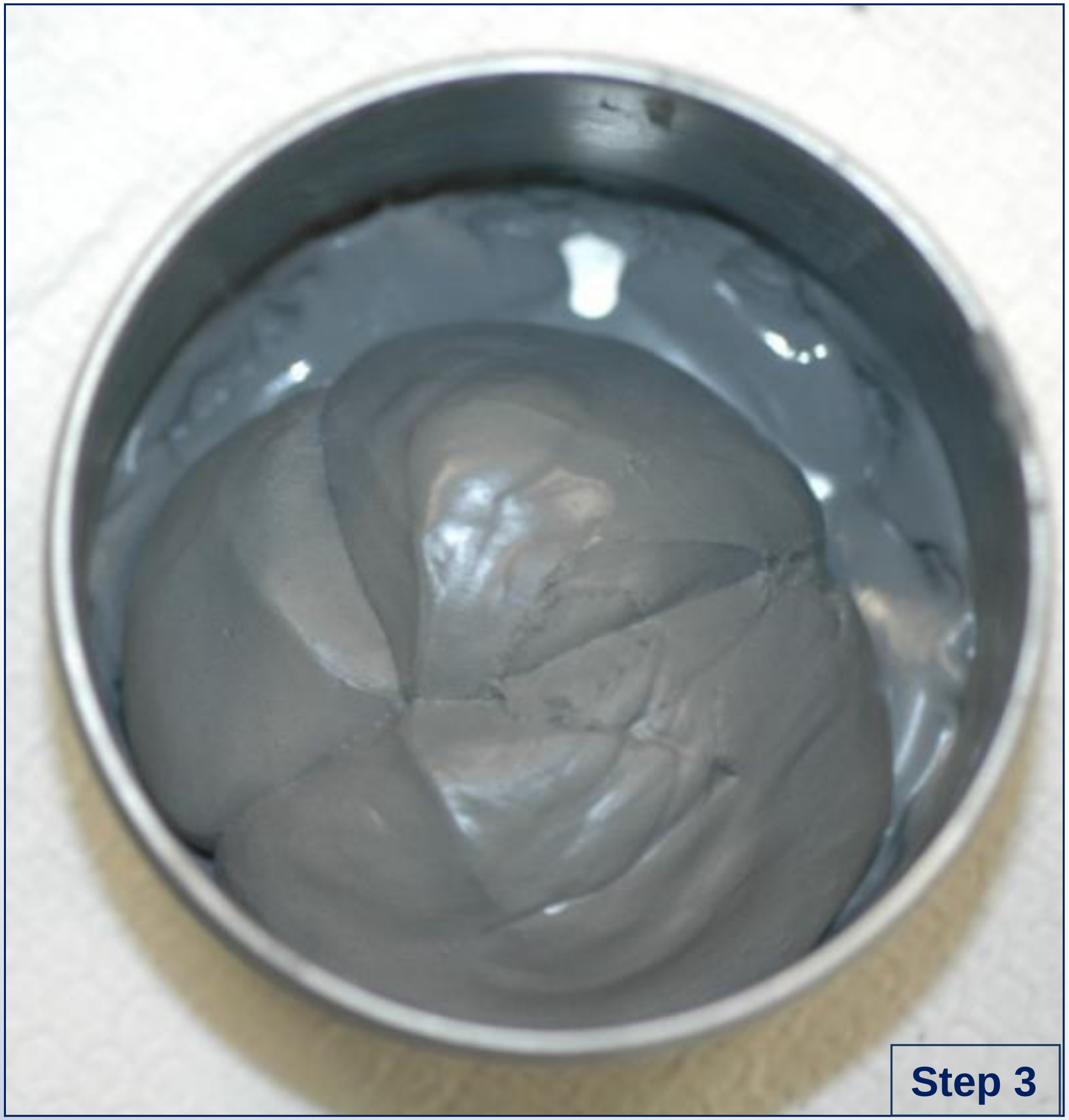
Mix A ($0.165 m^2/g$)

Step 2

Step 1: All ingredients; Mixed at 100% intensity for 60 min.; Material Temperature -- 128° F (2 min. after mixing is complete)

Step 2: Mixed at 100% intensity for 60 min.; Material Temperature -- 125° F (2 min. after mixing is complete)

Mix A ($0.165 m^2/g$)



Step 3

Step 1: All ingredients; Mixed at 100% intensity for 60 min.; Material Temperature -- 128° F (2 min. after mixing is complete)

Step 2: Mixed at 100% intensity for 60 min.; Material Temperature -- 125° F (2 min. after mixing is complete)

Step 3: Mixed at 75% intensity for 20 min.

Mix A (0.165m^2/g)

Step 1: All ingredients; Mixed at 100% intensity for 60 min.; Material Temperature -- 128° F (2 min. after mixing is complete)

Step 2: Mixed at 100% intensity for 60 min.; Material Temperature -- 125° F (2 min. after mixing is complete)

Step 3: Mixed at 75% intensity for 20 min.

Step 4: Mixed at 30% intensity for 10 min.

Mix A (0.165m^2/g)

Step 1: All ingredients; Mixed at 100% intensity for 60 min.; Material Temperature -- 128° F (2 min. after mixing is complete)

Step 2: Mixed at 100% intensity for 60 min.; Material Temperature -- 125° F (2 min. after mixing is complete)

Step 3: Mixed at 75% intensity for 20 min.

Step 4: Mixed at 30% intensity for 10 min.

Step 5: Mixed at 50% intensity for 8 min. and 20% intensity for 3 min.

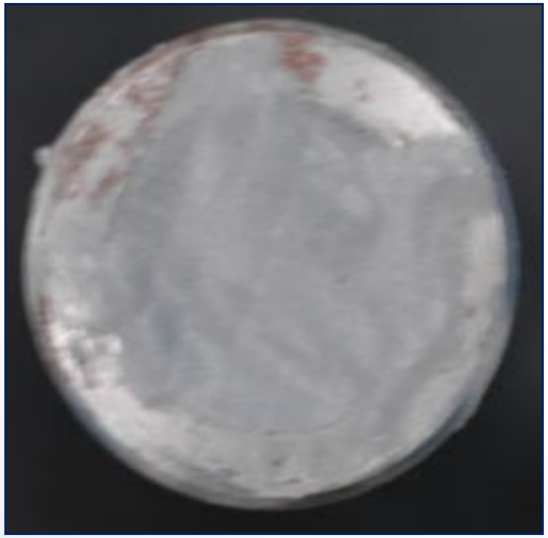
Mix A: In-Situ Mixing and Casting: IHE GAP Tube

End of mix product -- uncured -- Top view
(50% intensity for 8 min., 20% for 3 min.)

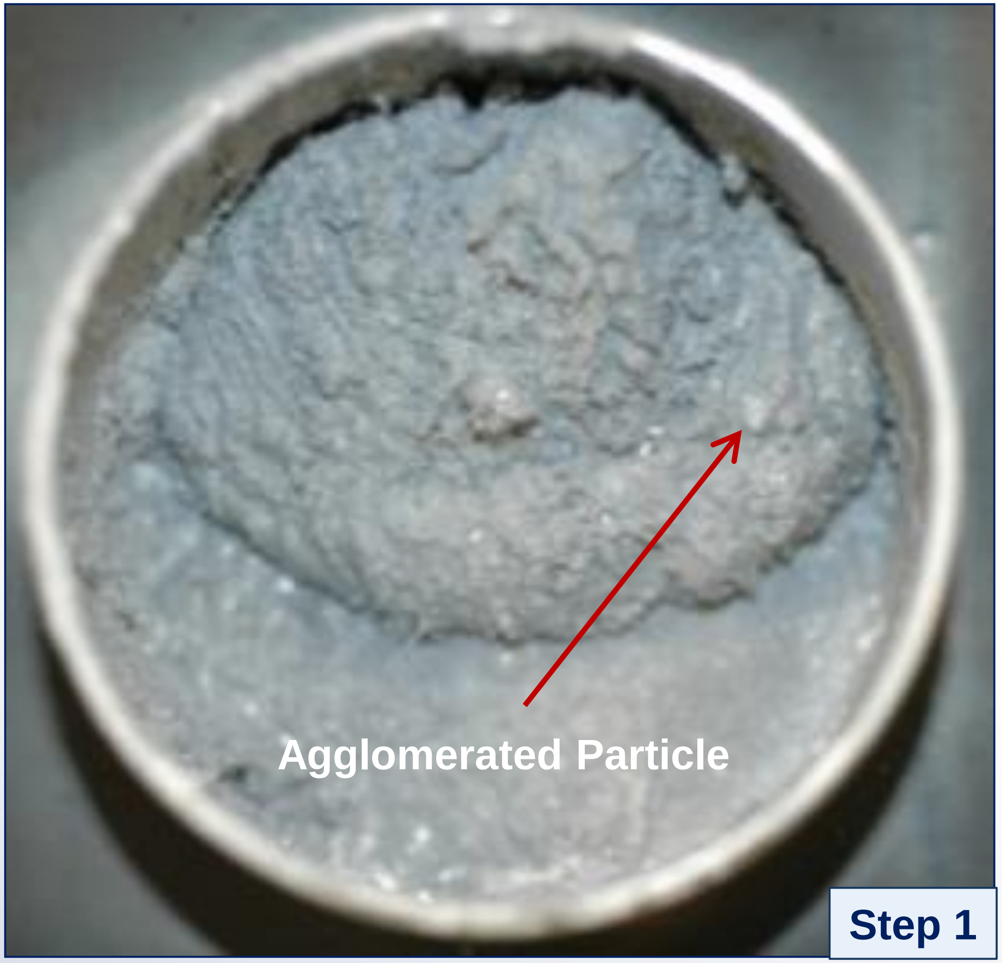
Post Cure:

Top ←

Bottom →



Mix B (1.65 m^2/g)



Step 1: ½ total solids; Mixed at 100% intensity for 20 min.; Agglomerates observed

Mix B (1.65 m^2/g)

Step 1: ½ total solids; Mixed at 100% intensity for 20 min.; Agglomerates observed

Step 2: All solids; Mixed at 100% intensity for 20 min.; Agglomerates observed

Mix B (1.65 m^2/g)

Step 1: ½ total solids; Mixed at 100% intensity for 20 min.; Agglomerates observed

Step 2: All solids; Mixed at 100% intensity for 20 min.; Agglomerates observed

Step 3: Mixed at 100% intensity for 60 min.; No agglomerates observed

Mix B (1.65 m^2/g)

Step 1: ½ total solids; Mixed at 100% intensity for 20 min.; Agglomerates observed

Step 2: All solids; Mixed at 100% intensity for 20 min.; Agglomerates observed

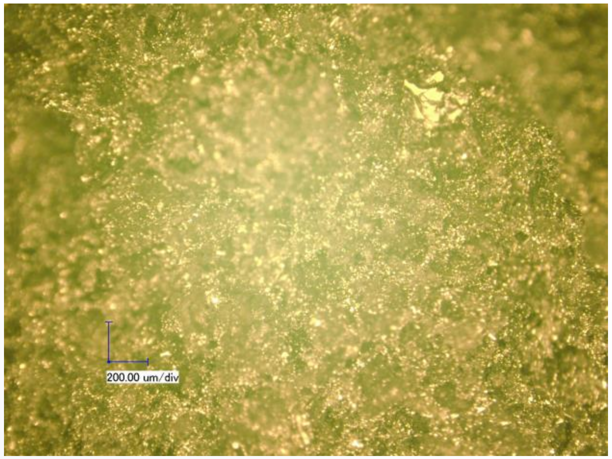
Step 3: Mixed at 100% intensity for 60 min.; No agglomerates observed

Step 4: Reduced mix vessel size; Mixed at 50% intensity for 60 min.; No agglomerates observed

Optical Microscopy

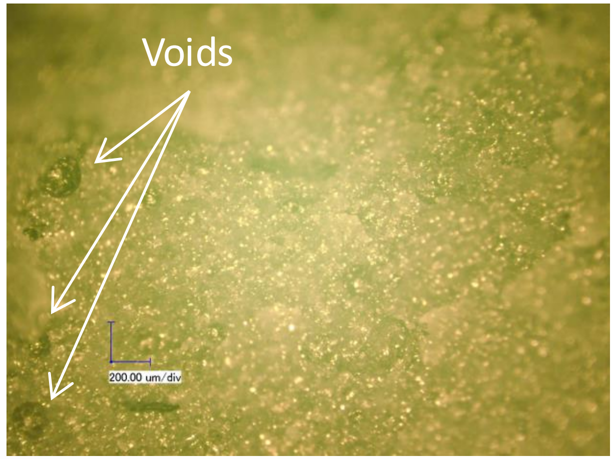
Baseline: 0.021 m^2/g

PBXN-109



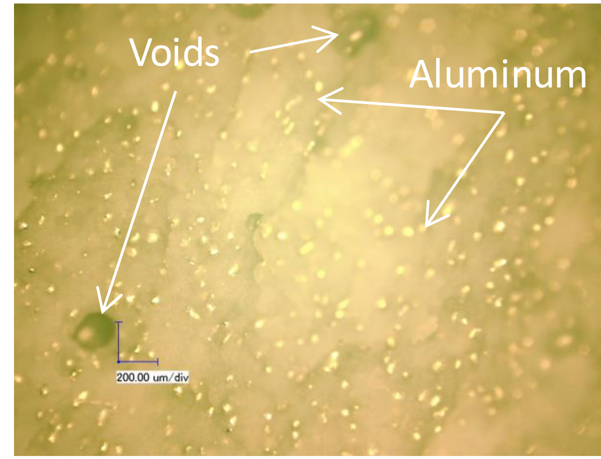
Mix A: 0.165 m^2/g

R-109-9



Mix B: 1.65 m^2/g

R-109-8



- **Optical images of the broken edges of explosive**
- **Baseline mix was processed in a planetary mixer**
- **RAM mixes were not processed under vacuum**
- **The RAM samples appear completely homogenous with no evidence of particle agglomeration**

Conclusions

- Initial Resodyn energetics test indicated the energetics evaluated are not adversely affected by the RAM energy input
- Propellant ballistic and tensile properties are similar for Resodyn and Baker Perkins mixes
- RAM can be used to effectively mix extremely viscous explosive formulations
  - In-situ mixing and casting is possible in small diameter test samples
- No particle agglomeration is evident in Resodyn mixed explosive

Acknowledgements

- Jeff Roquemore
- Dave Ciaramitaro
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Questions