Novel ARDEC Igniters for Gun Systems

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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STAR ATO
High Performance Igniter

Problems:

- Benite doesn't perform as well as $BKNO_3$ in 120MM tank rounds
- Benite gives inconsistent performance results.
- Future rounds need smaller igniter tubes.

Solution:

- ARDEC has developed an igniter formulation
  - **Excellent and consistent performance**
  - **Less sensitive than Benite**
  - **Is more energetic than Benite.**
  - **Extrudable**
  - **Smaller Ignition Delays**

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High Performance Igniter

Possible Causes:

- **Type IV $BKNO_3$ igniter has an oxygen balance of -35%**
  - After firing, all of the oxygen in the barrel is exhausted
  - Boron combustion requires large amounts of oxidizer
  - Opening of breach allows a rapid influx of oxygen which ignites uncombusted boron (or other fuel)

$BKNO_3$

- Made of:
  - 70% Potassium Nitrate
  - 30% Boron
- Easily ignited at low **P**.
- High Gas Content
- Burn Rate insensitive to **P**.
- Hygroscopic (less than Black Powder)
- Flare Back (Incomplete oxidation)

Benite

- Made of:
  - 40% Nitrocellulose
  - 6.3% Sulfur
  - 44.3% Potassium Nitrate
  - 9.3% Charcoal
  - 0.5% Ethyl Centralite
- Performance as an igniter is adequate for tank applications.

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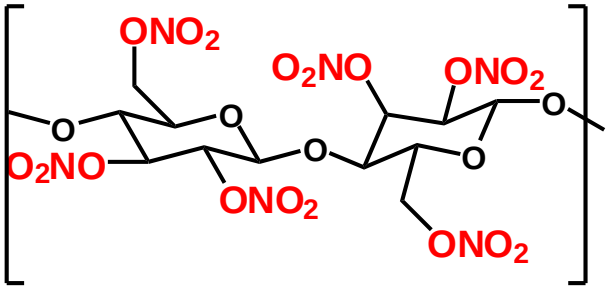
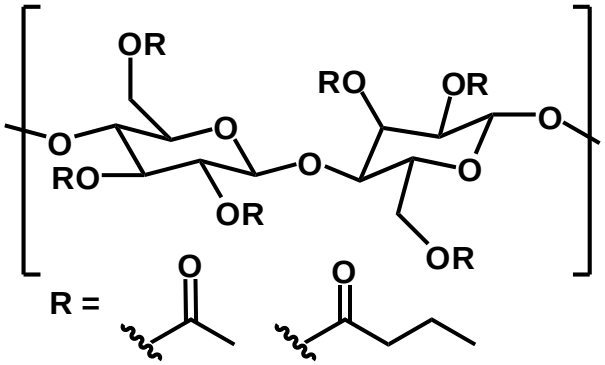
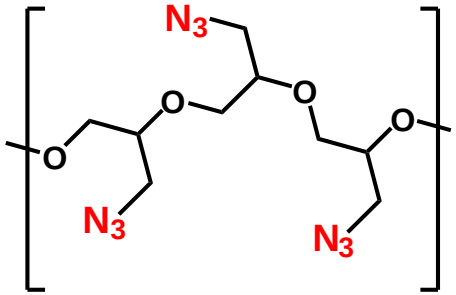
Properties of Binders Considered



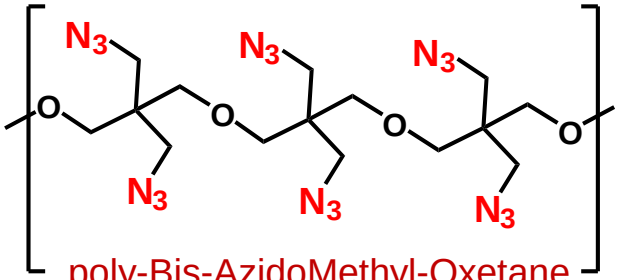
Nitrocellulose
ρ = 1.66 g/cc
ΔH_f = -690 kJ/mol
T_v = 3331 K
O.B. = -31%



Cellulose Acetate/Butyrate
ρ = 1.22 g/cc
ΔH_f = -1630 kJ/mol
T_v = 1052 K
O.B. = -160%



Glycidyl Azide Polymer (GAP)
ρ = 1.29 g/cc
ΔH_f = 176 kJ/mol
T_v = 2288 K
O.B. = -121%



poly-Bis-AzidoMethyl-Oxetane
ρ = 1.30 g/cc
ΔH_f = 373 kJ/mol
T_v = 2246 K
O.B. = -124%

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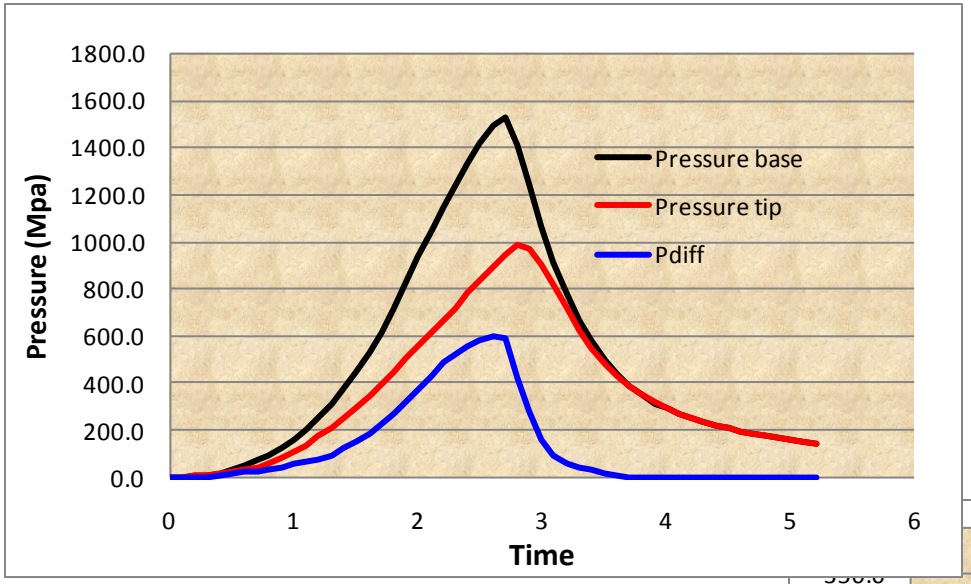
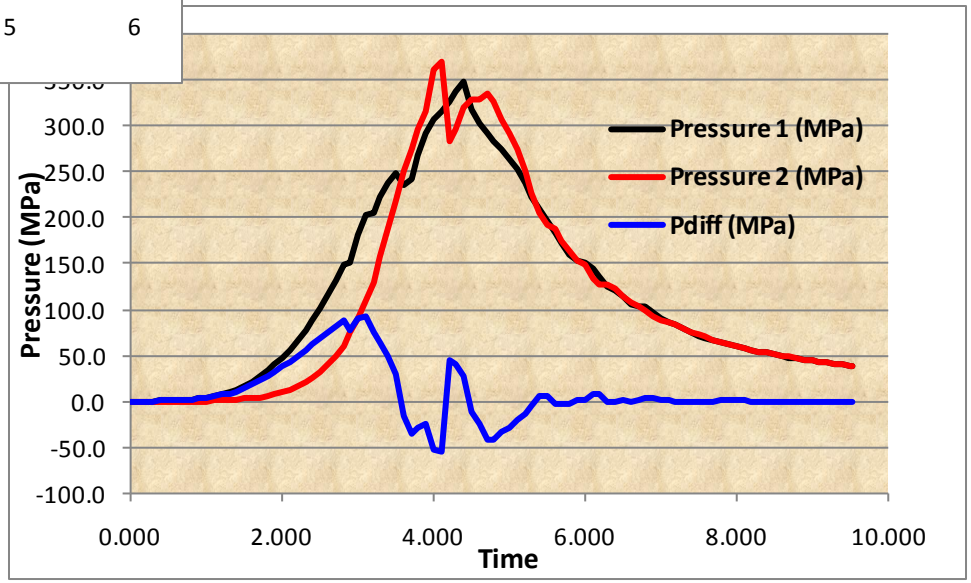
FNGUN Analysis



- Instantaneous Ignition along the igniter tube.
- No Pressure Differentials.

- Staged Ignition from the middle of the igniter tube.
- -50 MPa Pressure Differentials.



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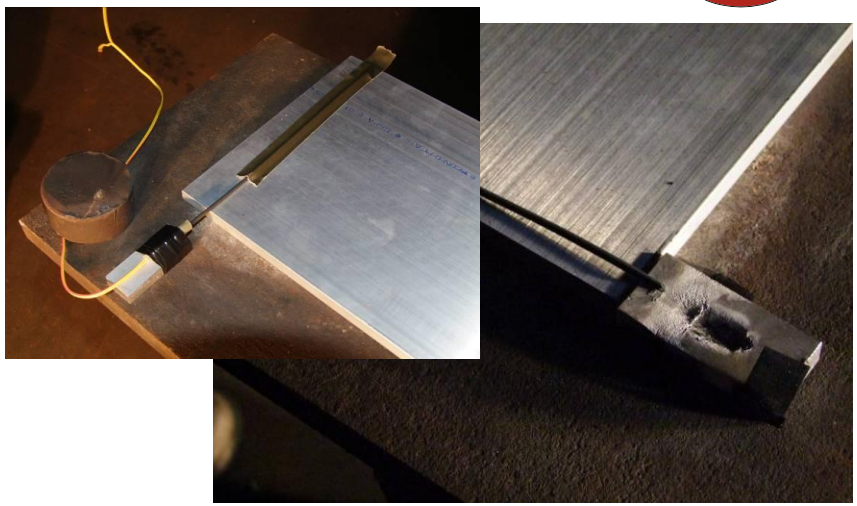
Sensitivity Analysis

Formulation	Igniter Sensitivity			
	Impact ERL (cm)	BOE	Friction (GO / No GO) (N)	ESD (J)
Benite	18.8	6 of 10	288 / 252	>0.25
BKNO3	23.2	10 of 10	> 360	>0.25
PAI-8556	22.4	7 of 10	240 / 216	>0.25
PAI-8557	24.6	5 of 10	324 / 288	>0.25
PAI-8558	>100	0 of 10	252 / 240	>0.25



Small Scale Burn

Material	Burn Time	Explosion	Detonation	Pass/ Fail
PAI-8556	Less 1 Sec.	NO	NO	Pass
	Less 1 Sec.	NO	NO	Pass
	Less 1 Sec.	NO	NO	Pass
PAI-8557	Less 1 Sec.	NO	NO	Pass
	Less 1 Sec.	NO	NO	Pass
	Less 1 Sec.	NO	NO	Pass
PAI-8558	2.01 Sec.	NO	NO	Pass
	2.79 Sec.	NO	NO	Pass
	3.05 Sec.	NO	NO	Pass

Critical Diameter

Lot #	Diameter	Result
8551	0.1345	NOGO
8551	0.1350	NOGO
8558	0.1405	NOGO
8558	0.1415	NOGO
8556	0.1420	NOGO
8556	0.1440	NOGO
8557-3	0.1400	NOGO
8557-3	0.1385	NOGO

Thermal Stability

Material	Starting Weight	Total Loss	Pass - Fail
PAI 8556	50.4135gms	.1464gms	PASS
PAI 8557	50.2485gms	.2614gms	PASS
PAI 8558	50.2745gms	.1545gms	PASS

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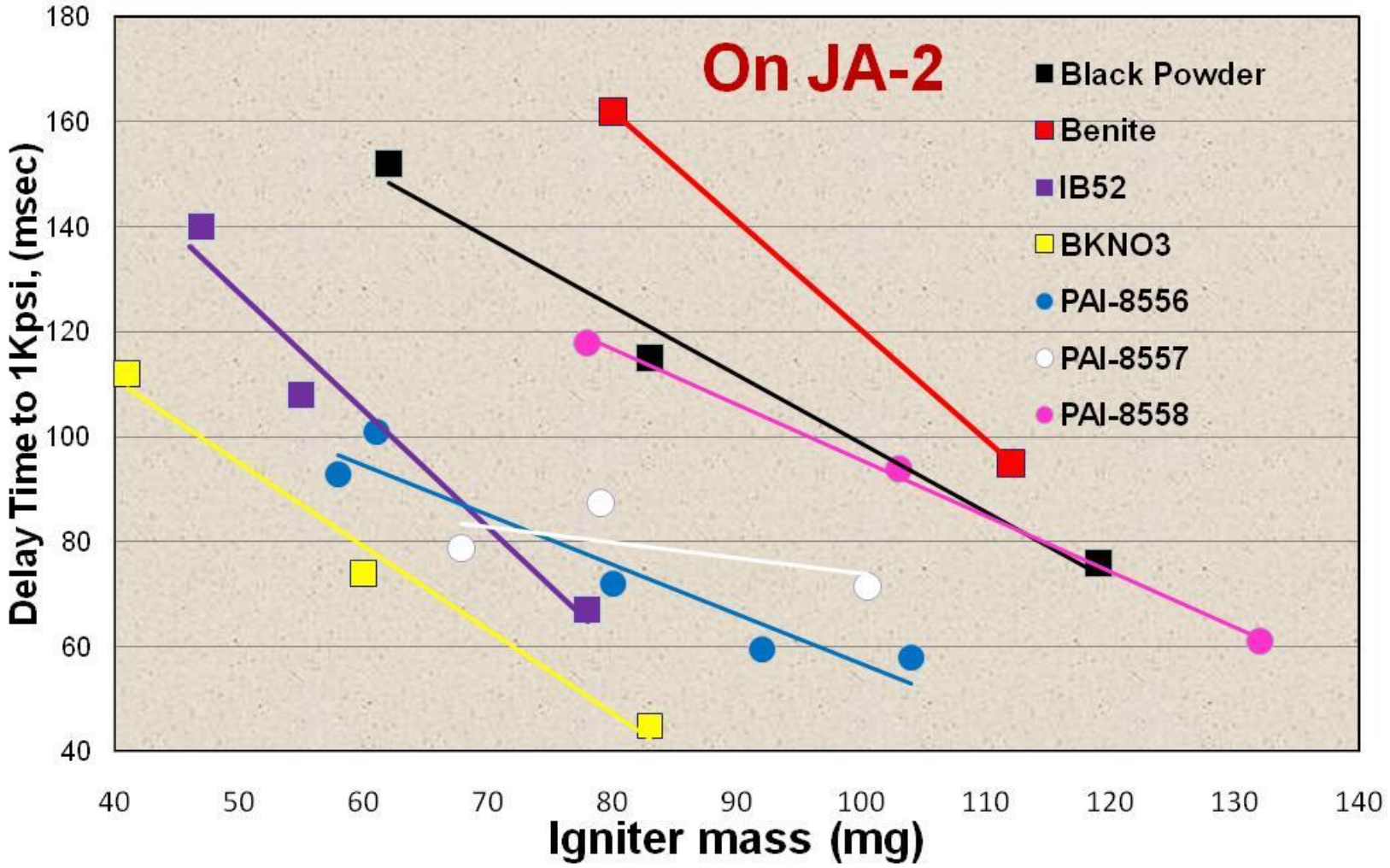
Small Scale Ignitability Study



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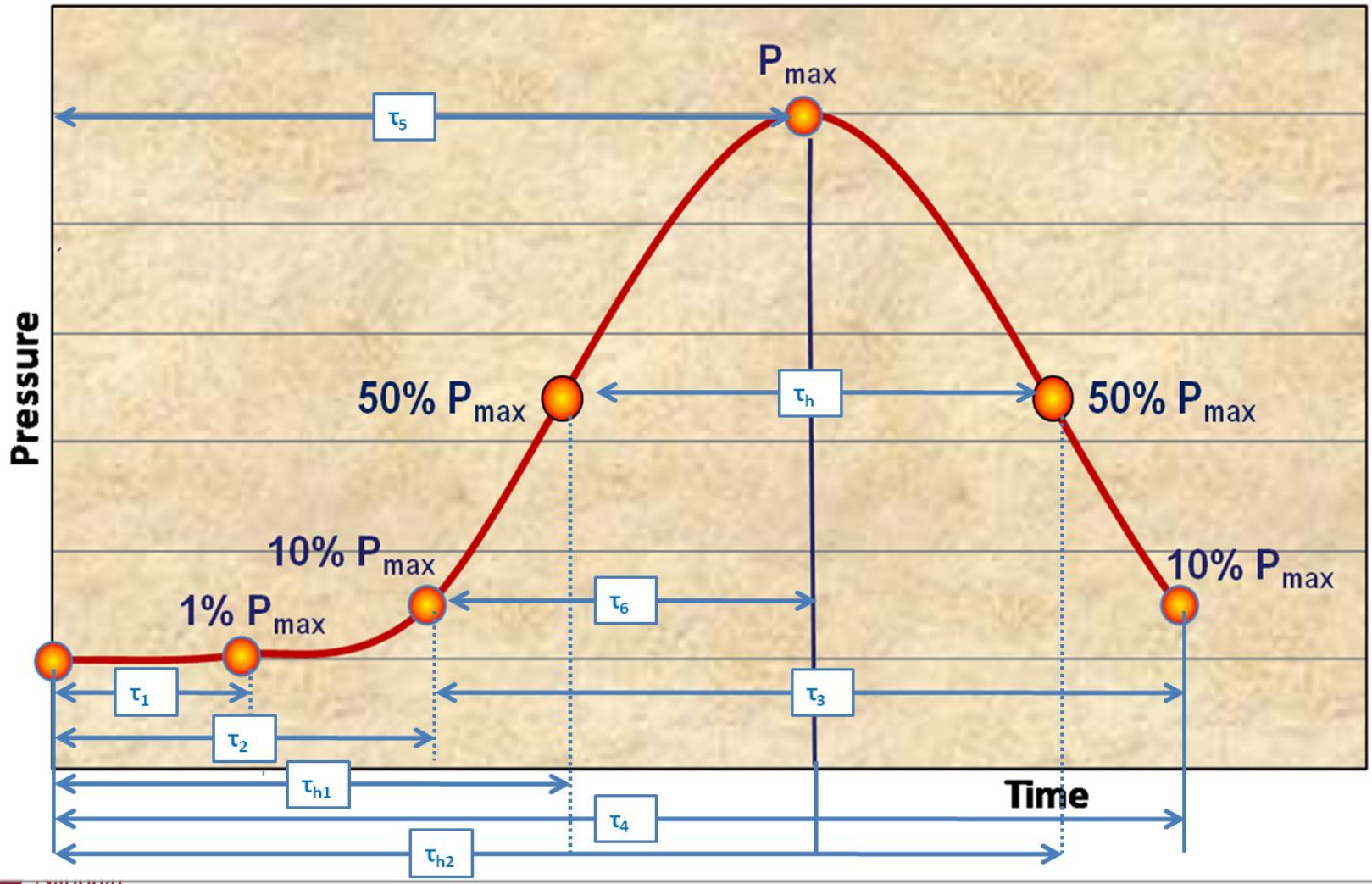
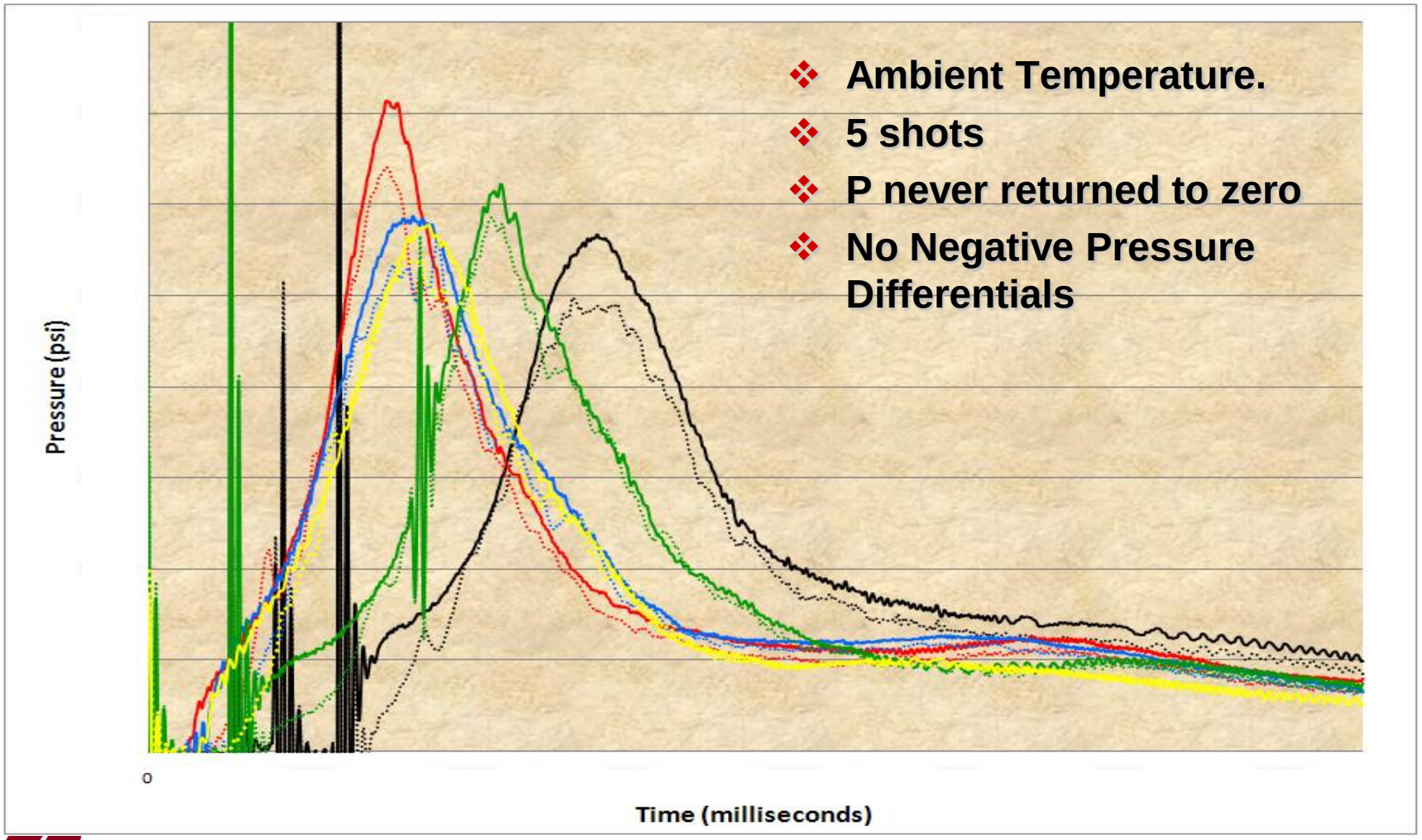
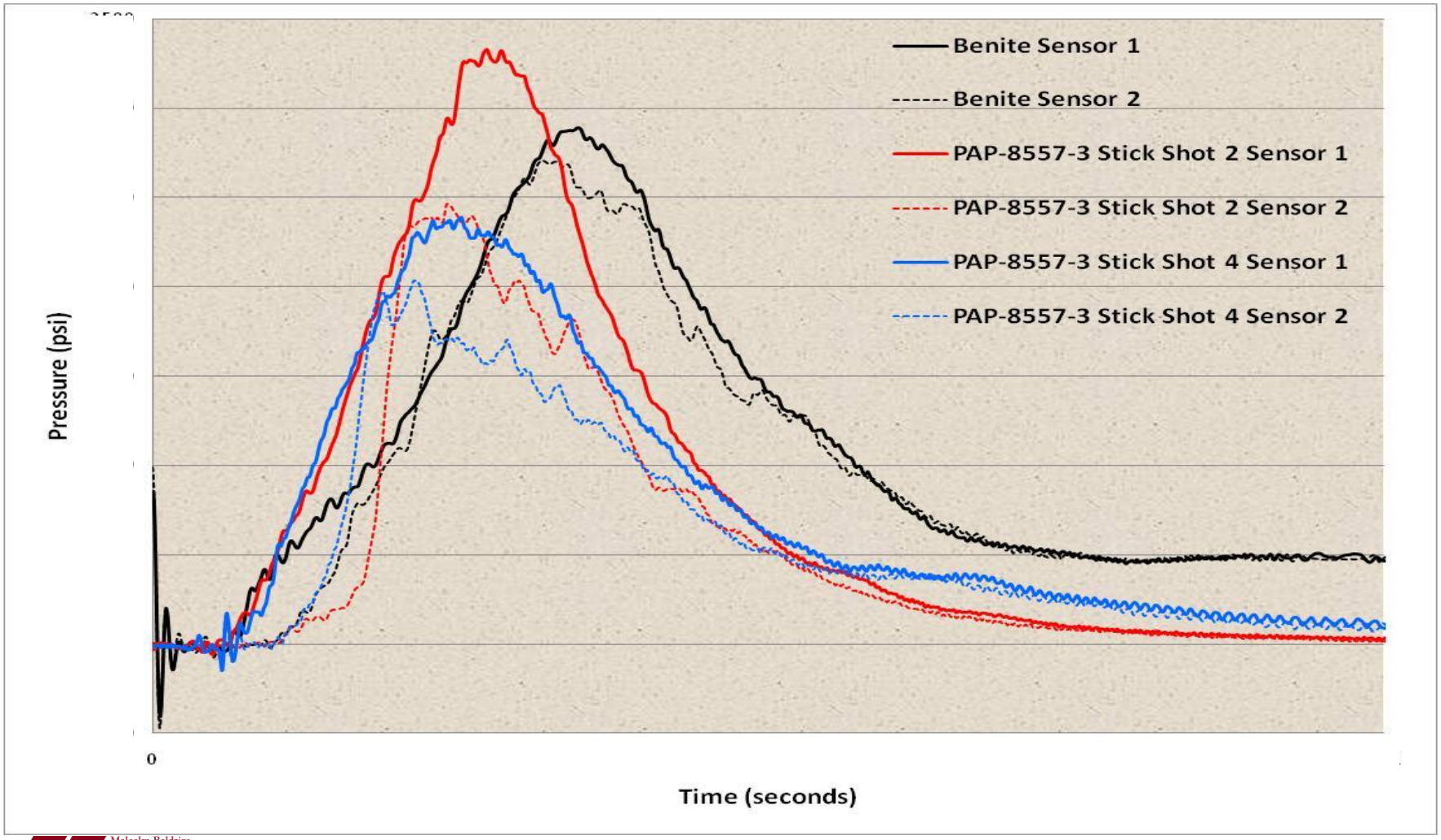
Expected Data



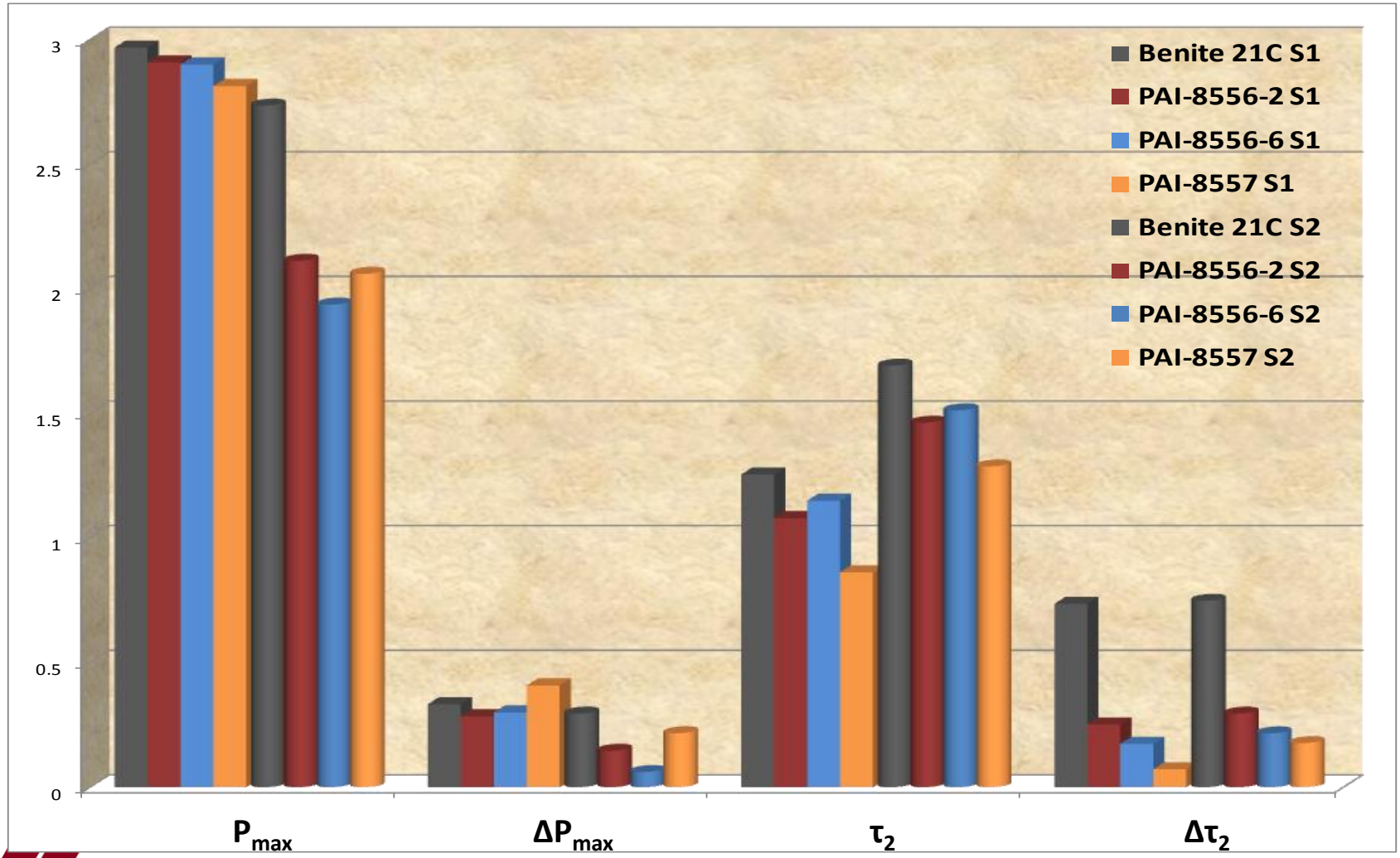
Benite at Ambient Temperature



PAI-8557 Un-Ground $BKNO_3$



Analysis of P_{max} and t_2



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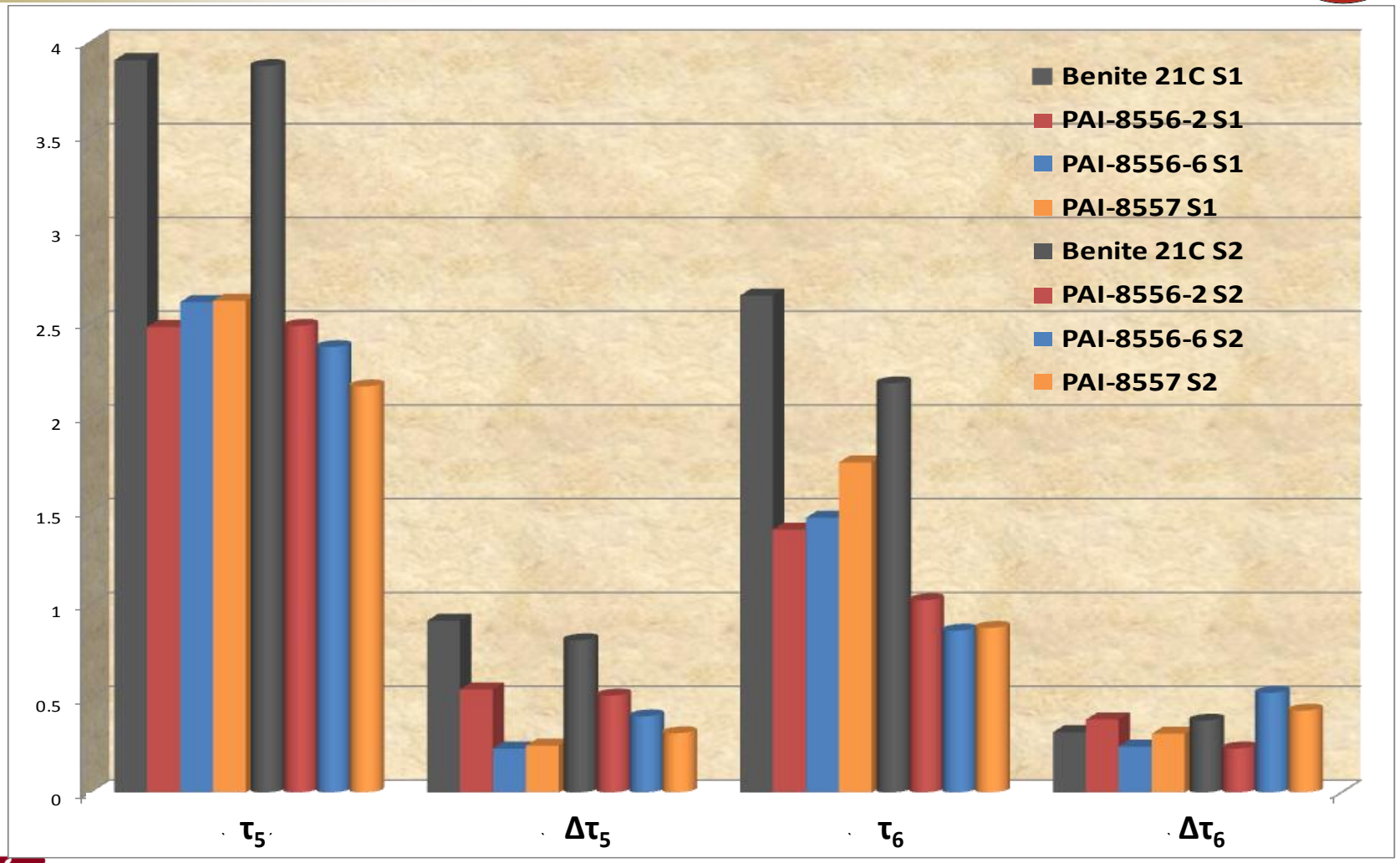
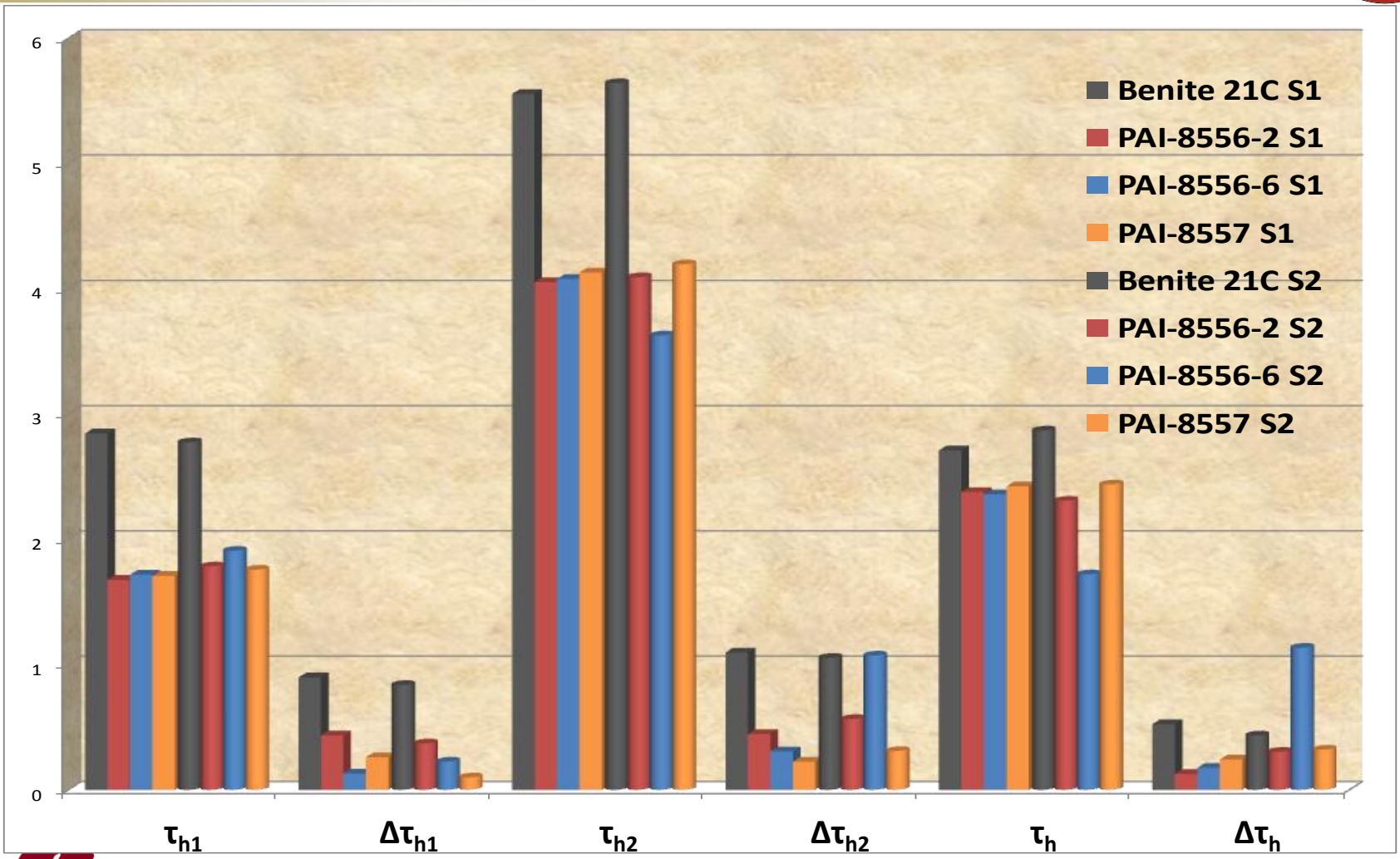
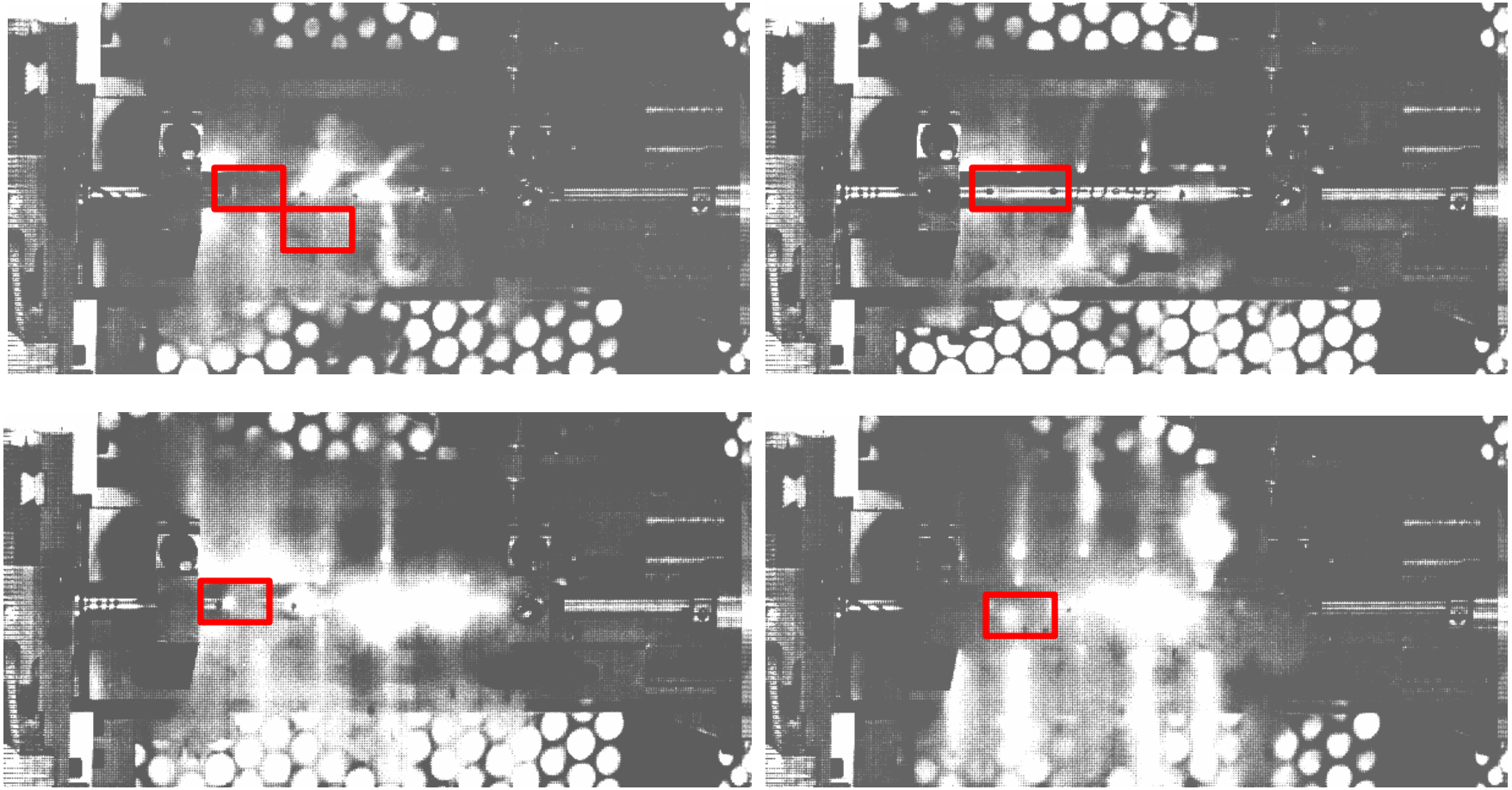
Analysis of t_5 and t_6



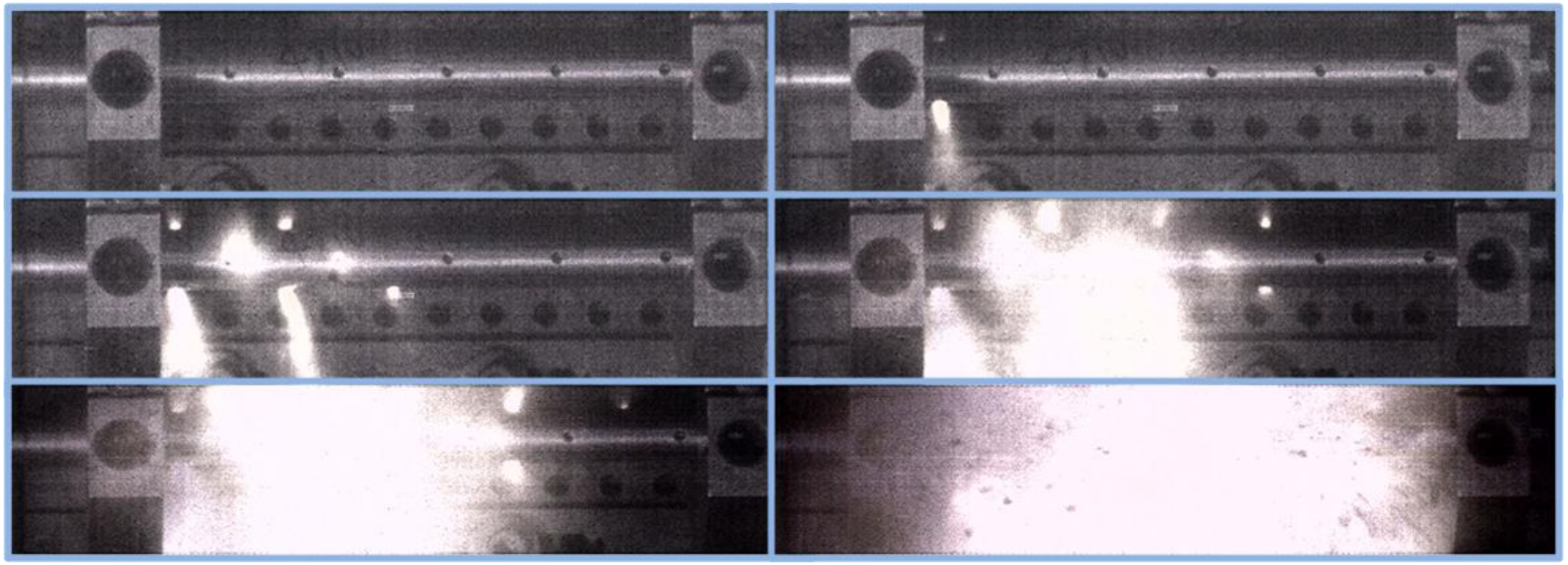
Analysis of t_{h1}, t_{h2}, and t_h



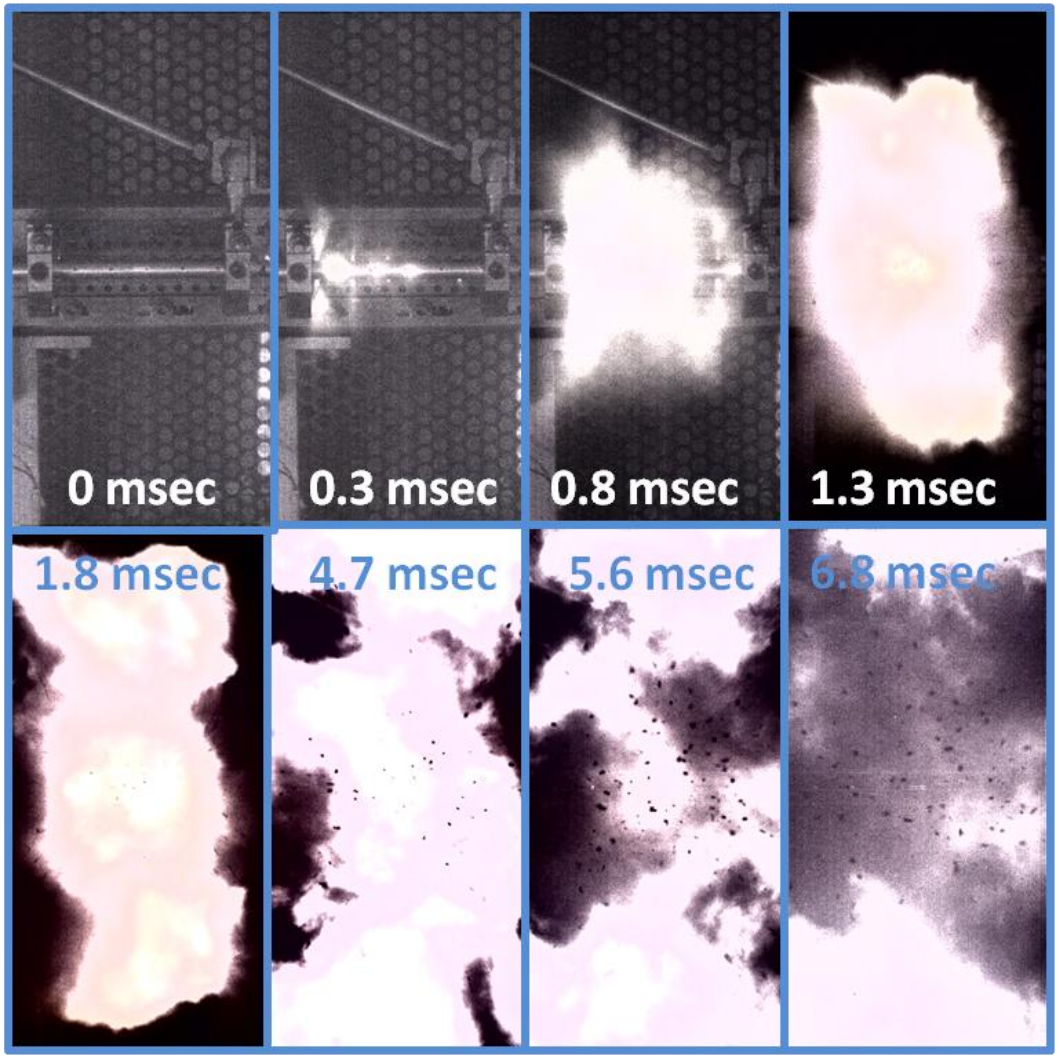
High Speed Video Stills of Benite Igniter at Ambient Temperature



High Speed Video Stills of PAI-8556 at Ambient Temperature



High Speed Video Stills of PAI-8556 at Ambient Temperature



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Conclusions

- Benite was found to have significant shot to shot variability in terms of pressure and time.
- Extrudable $BKNO_3$ analogue igniters were able to achieve P_{max} faster than benite with less variance in ignition delays and output pressures than benite demonstrating that the analogue igniters are more consistent.
- High speed video of the ignition events also demonstrated more hot particle and flame generation in the $BKNO_3$ analogue igniters in comparison to benite.