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U.S. Army Research, Development and Engineering Command

Characteristics of Propellant Bed Response When Subjected to High - Velocity Fragment Impact

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Brian Krzewinski
U.S. Army Research Laboratory
brian.e.krzewinski.civ@mail.mil
410-278-6206

Outline

- Purpose
- Assumptions
- Set up
- Results
- Conclusion
- Future plans

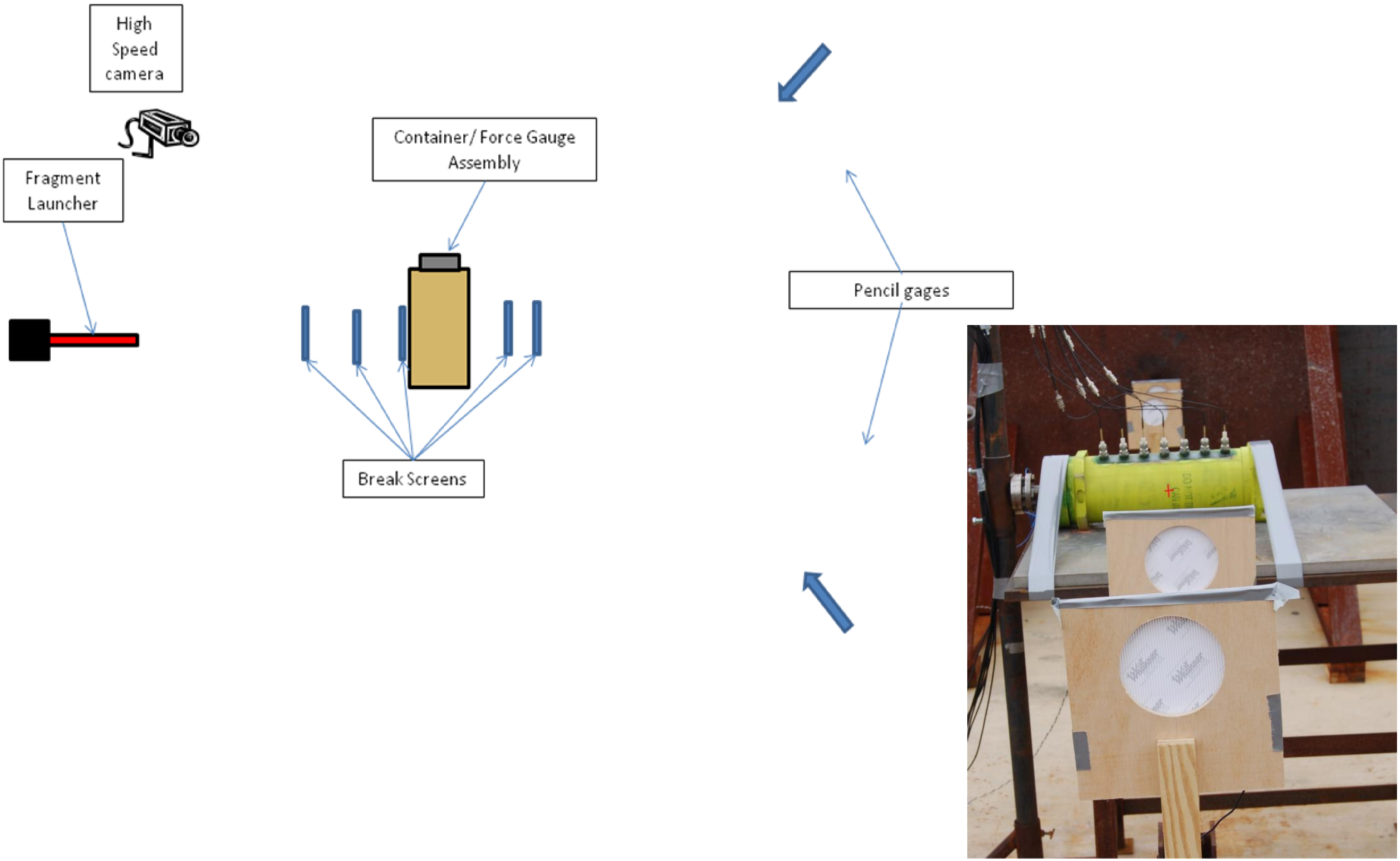
Purpose

- Historical Insensitive Munitions (IM) testing of large-caliber gun propulsion systems has typically resulted in violent reaction (type III or IV) for Fragment Impact (FI)
- Fragments from these reactions are hazardous to any personnel or equipment nearby
- This problem has been identified as a technological gap within the IM Plan of Actions and Milestones (POA&M) of several large-caliber gun propulsion systems
- Solving this technology gap by 2018 was identified as a primary goal by the Joint IM Technology Program (JIMTP) lead for the Large caliber gun propulsion Munition Area Technology Group

Assumptions

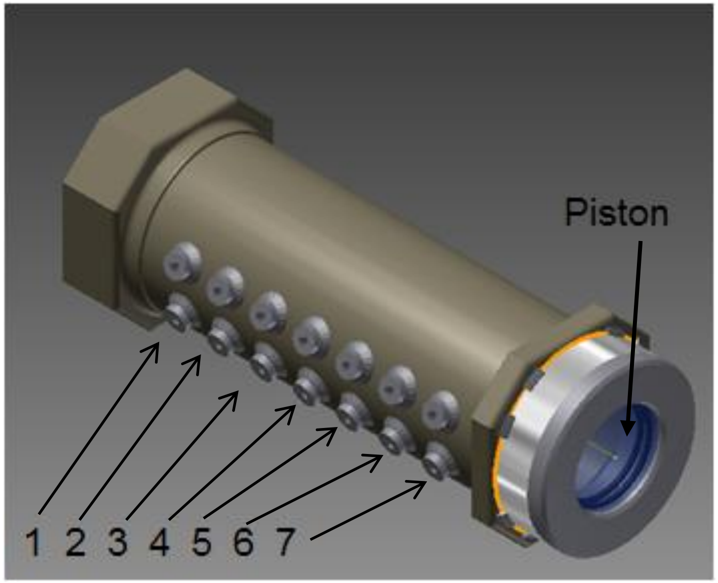
- The reaction always commences somewhere along the line of the fragment's trajectory and subsequently propagates away from this point
- There will be mechanically damaged energetic materials in the region of impact of varying size, which can cause non-uniform gas generation
- A strong compressive wave travels through the propellant bed away from the point of impact, which compacts the propellant bed and ultimately results in a substantial mechanical loading event that leads to the failure of the container

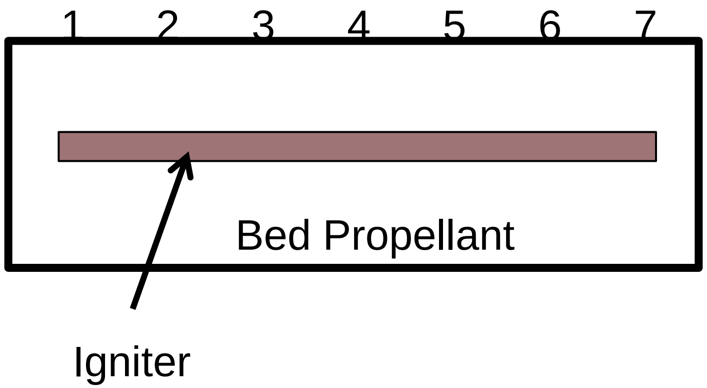
Experimental Setup



Generic Test Container

- 6 in diameter tube
- Internal length 17 in
- One end has a pin locking lid
- Other end incorporates a piston assembly
- 1 or 2 rows of embedded instrumentation





Instrumentation

- Piston assembly and piezoelectric force transducer to measure the compressive force at one end of the container
- Piezoelectric pins to measure reaction front in the propellant bed
- Fiber optic assemblies to measure ignition time of arrival
- Time of arrival screens to measure fragment velocity
- High-speed video of the event to look for anomalies

Test Matrix

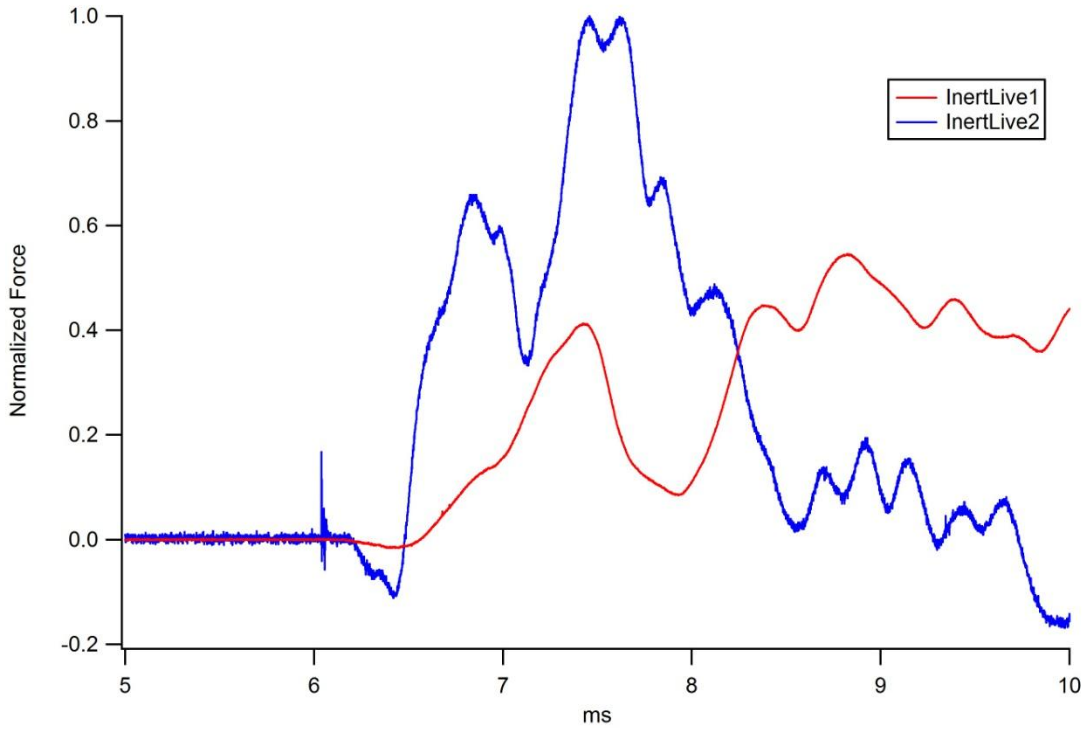
Test Number	Propellant	Igniter	Fiber Optics
1	Live	Live	Yes
2	Live	Inert	Yes
3	Inert	Live	Yes
4	Live	Live	No
5	Live	Inert	No
6	Inert	Live	No

Inert Propellant /Live Igniter Results

- Test 3 Inert/Live velocity of 8211ft/s
  - Type V (Burning reaction)
- Test 6 Inert/Live velocity of 8340ft/s
  - Type V (Burning reaction)
- Both containers had a small entrance hole slightly larger than the fragment diameter and a petaled exit hole
- No other damage was observed

Inert Propellant/Live Igniter Force Measurements

- Peaks not identical but are of the same approximate magnitude
- Likely due to propellant bed variability

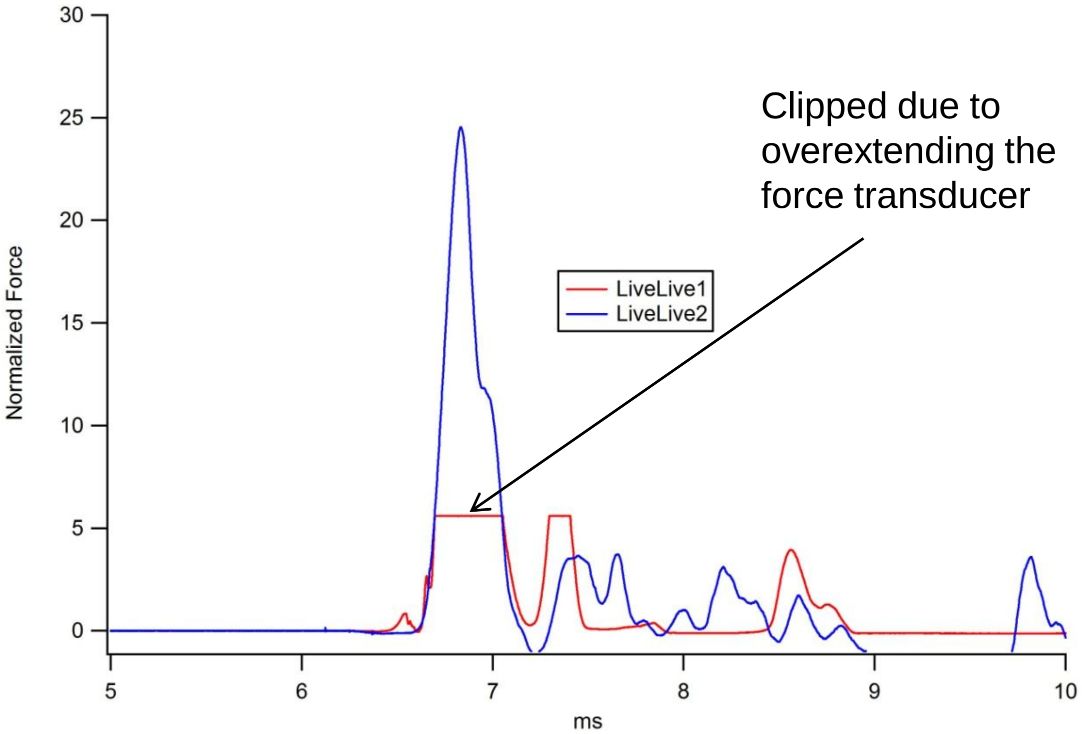


Live Propellant/Live Igniter Results

- Test 1 Live/Live velocity of 8244ft/s
  - Type III (Explosion reaction)
- Test 4 Live/Live velocity of 8309ft/s
  - Type III (Explosion reaction)
- Both containers split into many pieces, bent their end cap around the locking pin, and left propellant marks on the plunger end
- Shielding prevented end caps from leaving the immediate area

Live Propellant/Live Igniter Force Measurements

- Peak force over 24 times that of the inert/live experiments
- Peak duration similar for both live/live experiments

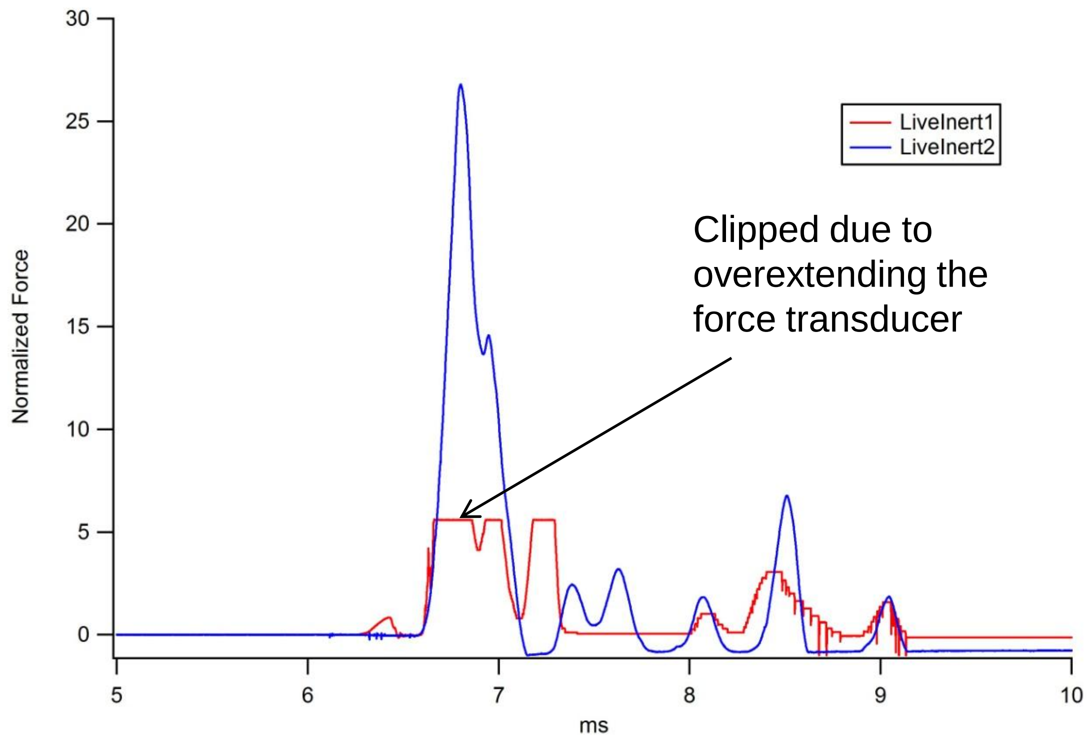


Live Propellant/Inert Igniter Results

- Test 2 Live/Inert velocity of 8287ft/s
  - Type III (Explosion reaction)
- Test 5 Live/Inert velocity of 8215ft/s
  - Type III (Explosion reaction)
- Both containers split into many pieces, bent their end cap around the locking pin, and left propellant marks on the plunger end
- The welds holding the piston together also broke on test 2
- Shielding prevented end caps from leaving the immediate area

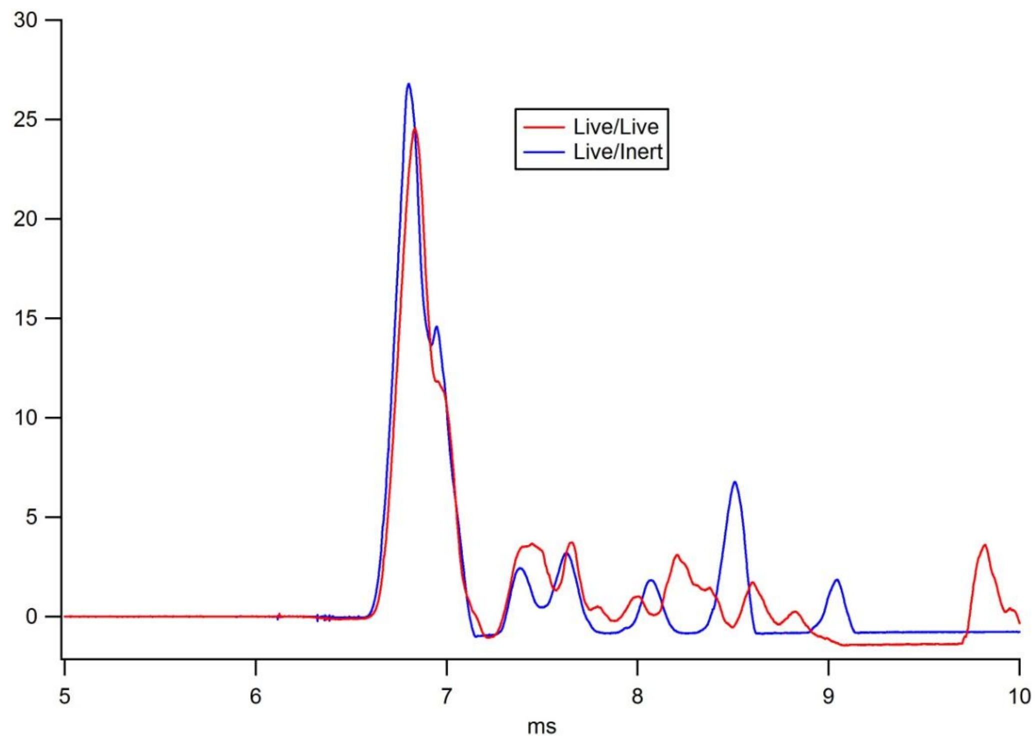
Live Propellant/Inert Igniter Force Measurements

- Peak force over 26 times the force witnessed in the inert/live experiment
- Peak duration similar for both live/inert experiments



Minimal Effect of Igniter Material

- Inclusion of live igniter material appears to have no effect on overall reaction mechanisms



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Piezoelectric Pin Results

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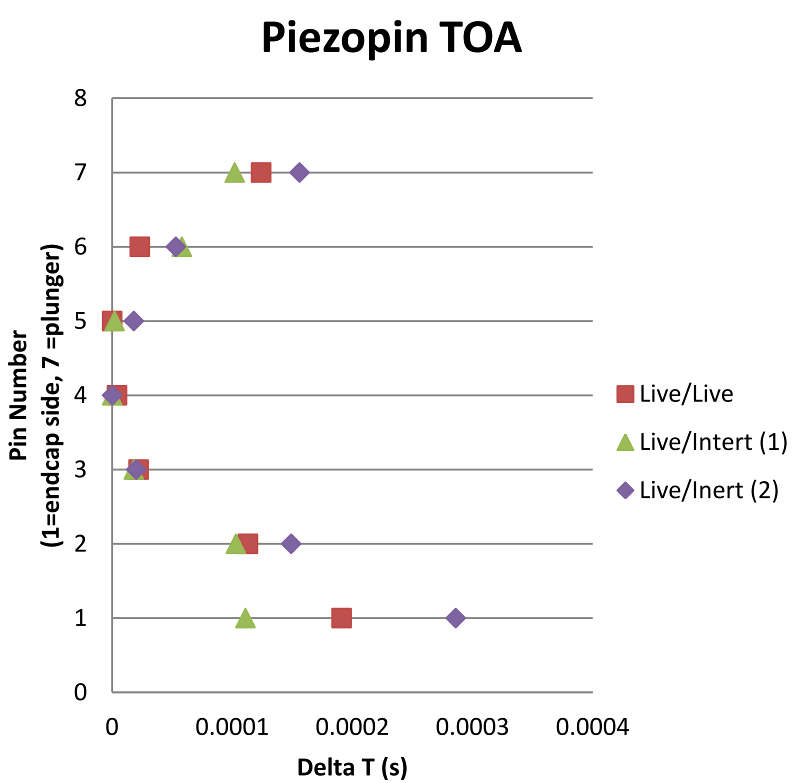
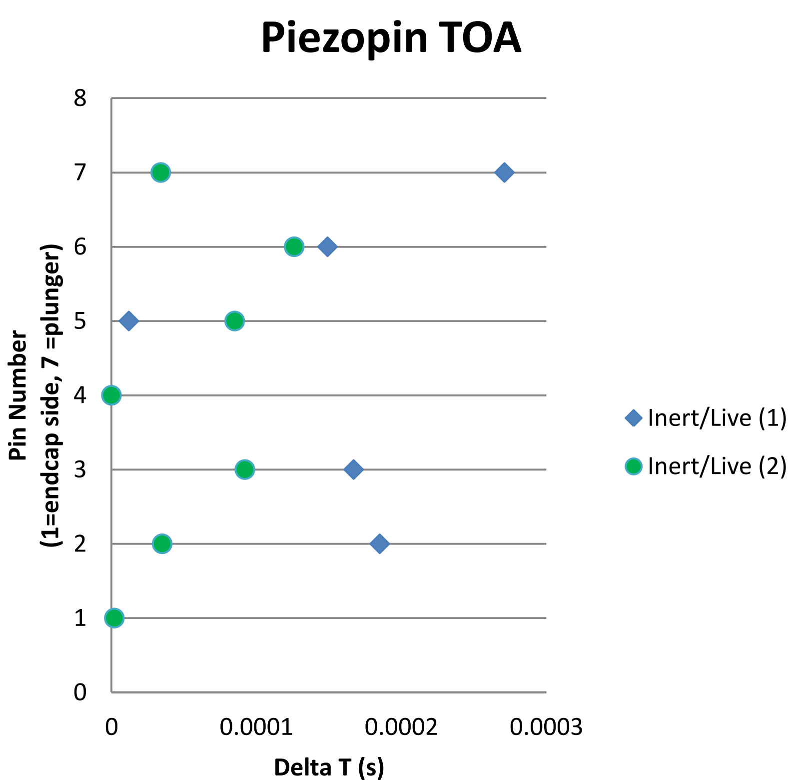
- Experiments with the live propellant react fairly symmetrical from the point of impact

Live Propellant



Inert Propellant



Conclusion

- A strong compressive wave appears to be traveling through the live propellant bed
- The response is fairly symmetrical when live bed propellant is used
- Container break up is due, in part, to the strong compressive wave
- There is little time available to mitigate the reaction using traditional venting schemes
  - Maximum force is reached roughly 1 ms after fragment impact

Future Plans

- Altering the deposited energy
  - Adding ballistic barriers
  - Lowering fragment velocity (majority of credible impacts are less than 8300 ft/s)
- Experimenting with other propellants to determine effects of propellant energies
- A completely inert experiment (to isolate the non reactive force)