U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMAMENTS CENTER

Test Development for Characterizing Electrically Controlled Energetic Materials

Kimberly Chung

U.S. Army CCDC – Armaments Center

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BACKGROUND

Electrically Controlled Energetic Materials (ECEMs)

- Materials that are electrically responsive to electrical stimulus
- Produce gas and flame when ignited (for gun propulsion systems)
- Objective: Develop a material where the output is controlled by the incoming electricity
  - Ignition in the presence of electricity
  - Tune burn rate after ignition
  - Quench reactions
- Benefits: Temperature compensation, in-flight course correction, simplification of ignition train
- Applications: Igniters, rocket motors, thrusters, etc.

DEVELOPMENT PROCESS

- ***Formulation***
  - Modification of existing propellant
  - Manipulation of nitrocellulose
  - Novel ingredients

- ***Electrode Configuration/Power Delivery***
  - Voltage and current settings
  - Electrode configuration

- ***Performance Tests***
  - Determine ways to meaningfully evaluate ECEMs
    - Ignitable – Does the material respond to electricity?
    - Quantitative – How does the material burn?

TEST DEVELOPMENT

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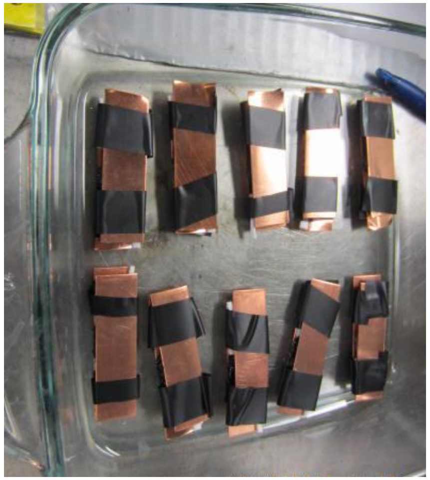
Proof-of-Concept Test

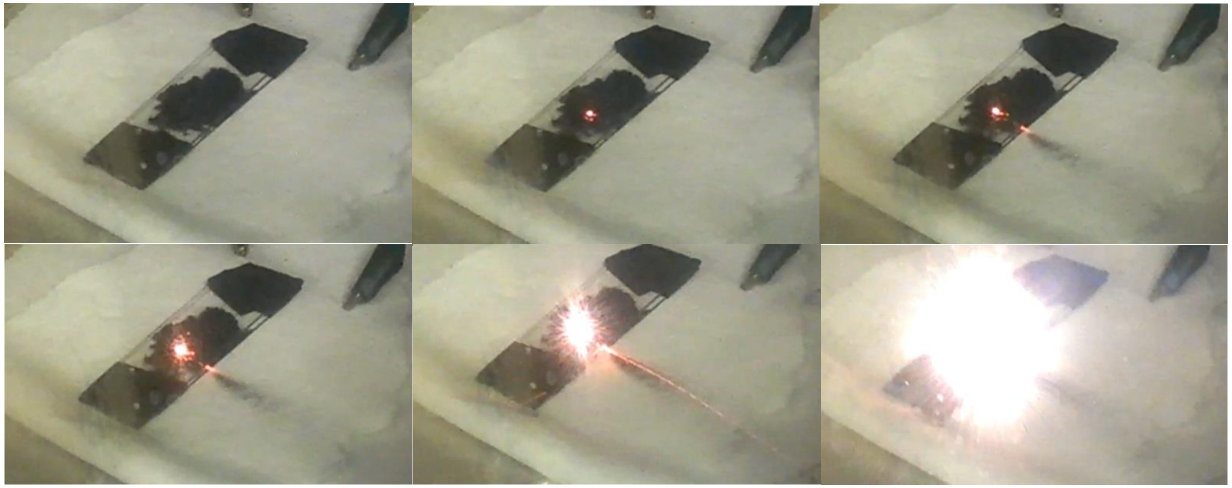
- Evaluate ignitability with the smallest amount of material
- Electricity is applied to determine if the material is responsive (burns and outgases) to electrical stimulation
- Configurations:
  - Glass slides with stainless steel electrodes
  - Two metal slides with Teflon spacers



TEST DEVELOPMENT

Proof-of-Concept Test – Glass Slides

- Glass slides allow for visual observation of any reaction
  - Easy to procure and cost effective
- Power delivered to samples affected by the thickness of the stainless steel wires
- Ignition was typically observed at one of the electrodes



TEST DEVELOPMENT

Proof-of-Concept Test – Metal Slides

- Increase area of contact between samples and electrodes
- Evaluated copper and aluminum slides
- Ignition is only visible from the gap between the copper slides
- Spacers are needed to
  - Ensure the slides do not come into contact
  - Provide a well to cast the material into

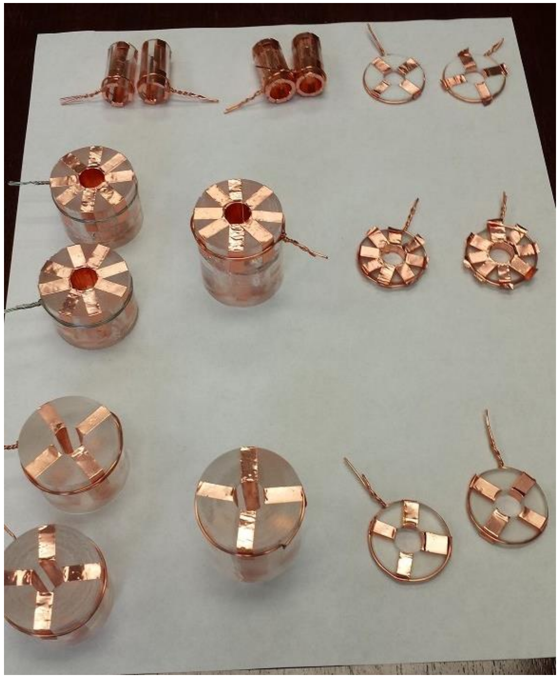
Spacers are used to prevent short circuits

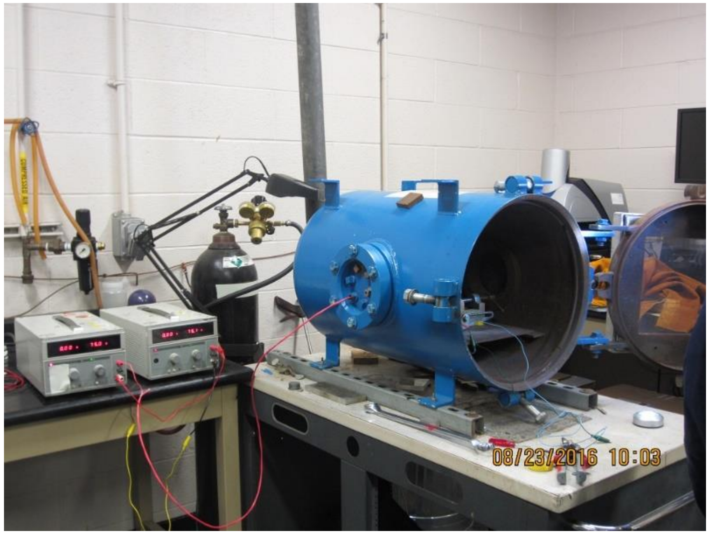
Ignition event with copper slides

TEST DEVELOPMENT

Cylinder Test

- Larger sample quantities: up to 5g of material
- Acrylic withstood the flame and temperature generation
  - Copper tape serves as the outer electrode(s)
  - The second electrode is a copper wire in the center of the fixture





TEST DEVELOPMENT

Cylinder Test

- Testing is conducted in an enclosed chamber which can be vented
- Cylinders are supported in a clamp or left free standing on a metal block
- Fixtures are not reusable

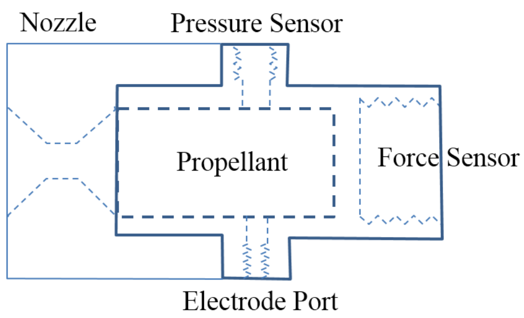
Sample secured in test chamber

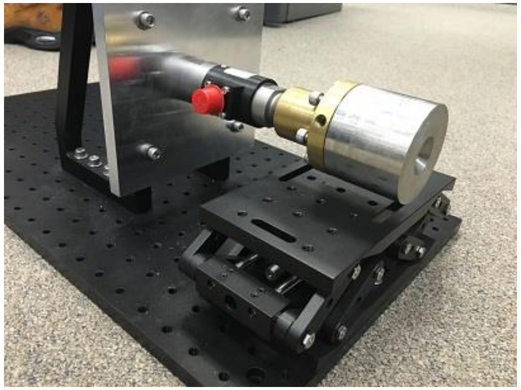
Sample is entirely consumed

TEST DEVELOPMENT

Subscale Thrust Fixture – First Iteration

- Fixture designed to collect pressure and force/thrust data
  - Generate data for predicting performance of scaled up rocket motors
- Copper test chamber (2.5mm x 5mm) serves as one electrode while a wire threaded in through a port will be the second electrode
- Stainless steel nozzle constricts the opening of the test chamber
- Threads used to interface various components presents hazards

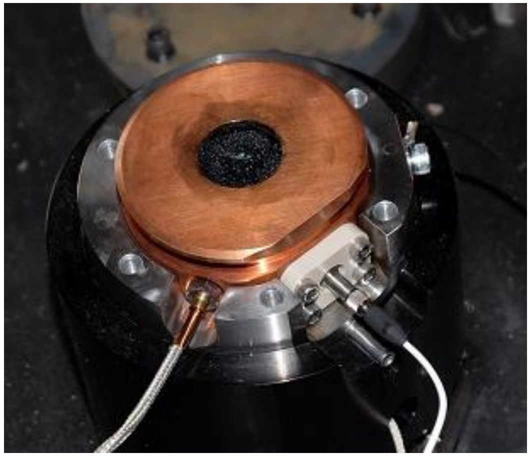




TEST DEVELOPMENT

Subscale Thrust Fixture – Updated Design

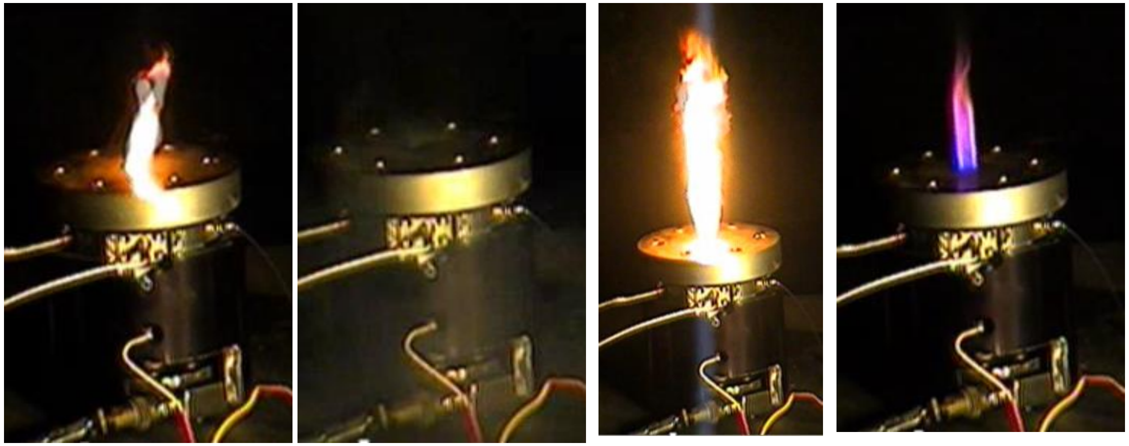
- Fixture designed to collect temperature, pressure and, thrust data
- Up to 50g of material can be loaded
- Test chamber contains seven electrodes to increase likelihood of ignition
- Can be modified to accommodate different electrode modules
- Easily interfaces with existing power supply
- No threads to minimize pinch points



TEST DEVELOPMENT

Subscale Thrust Fixture – Current Design

- Initial tests focused on achieving ignition
  - The maximum voltage was applied to the samples (223V)
- Standard and high speed video captured the event
- Flames were produced intermittently until all material was consumed
  - Voids in the sample chamber likely led to the inconsistent reaction

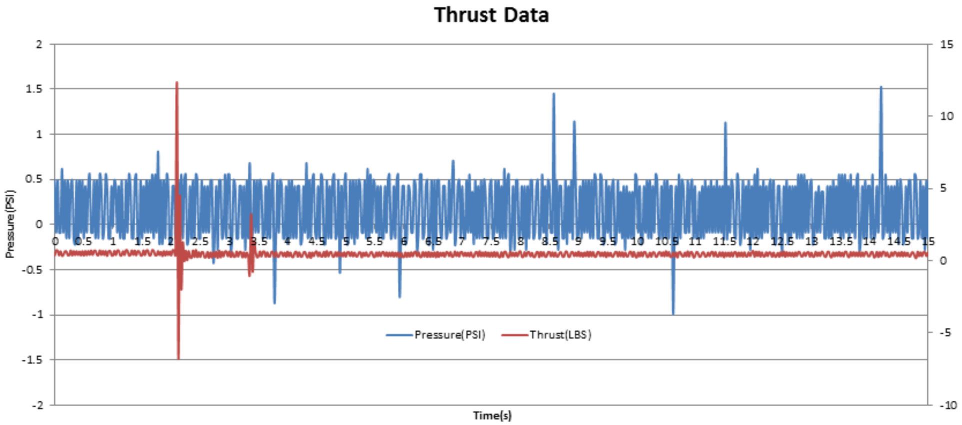


Images from standard video

TEST DEVELOPMENT

Subscale Thrust Fixture – Burn Event

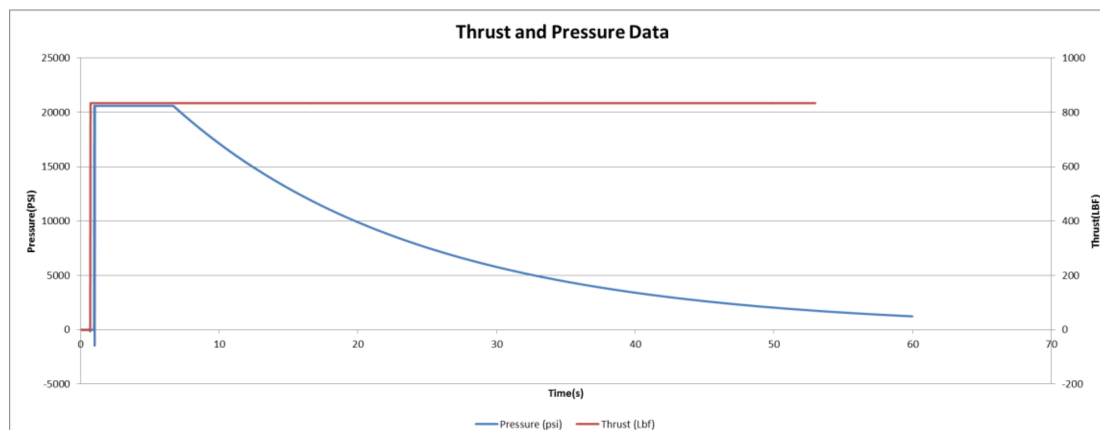
- The thrust data captured the irregularity of the reaction
  - Two distinct peaks for the thrust data are observed
  - The pressure gauge did not record significant data
- Temperature could not be captured due to the brevity of the reaction and the thermal mass of the test chamber



TEST DEVELOPMENT

Subscale Thrust Fixture – Deflagration Event

- Initiation occurred immediately after application of power
- The nozzle plates was destroyed
    - Recovered in multiple pieces
    - Bolts were sheared off
- Gauges were maxed out immediately after reaction



CONCLUSIONS

- Three tests were developed to screen and evaluate ECEMs
  - Proof-of-concept: qualitative information, small quantities
  - Cylinder test: qualitative information, small quantities
  - Subscale thrust fixture: quantitative information, medium quantities
- Data acquisition system has been verified
  - Pressure port must be relocated to capture gases produced
  - The temperature gauge is not useful due to the size of the test chamber
    - Removed in next iteration and can be considered if the test chamber has less mass.
- Quenching of ECEMs
  - Reaction is more difficult to quench in larger quantities

FUTURE WORK

- Testing
  - Redesign thrust fixture to avoid overpressurization
  - Reconfigure location of gauges
  - Update power supply
    - Capture voltage and amperage during the reaction
    - Determine ignition delay
  - Evaluate HERO safety

- Improve sample quality
  - Investigate vacuum casting techniques and formulations employed to improve voids

- Modeling
  - Feed data from subscale test fixture to model what is going on

BACKGROUND