RDECOM

GENERAL DYNAMICS
Ordnance and Tactical Systems

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Reactive Material Formulation Study for Surface Ignition of Explosives

May 2012

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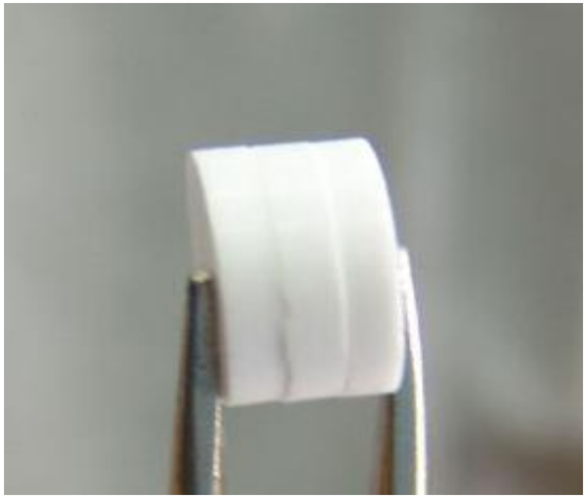
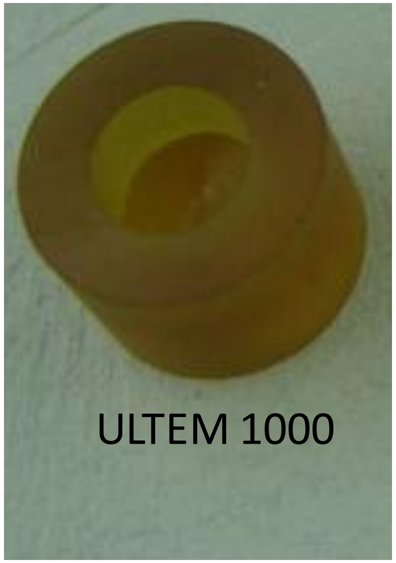
Introduction

- The objective of this presentation is to describe testing used to demonstrate the use of pyrotechnics to force a controlled burn in on the surface of explosive billets
  - Preliminary work presented Al-Shehab, N., E.L. Baker, J. Pincay, "Using Energetic Materials to Control Warhead Ignition During Slow Cook-Off", Insensitive Munitions & Energetic Materials Technology Symposium, Tucson, Arizona 11-14 May 2009
  - Pyrotechnic material required to reliably ignite between 250-300F
  - Material 1 selected from that work the basis for current effort
- During SCO testing at 6-deg F/hr. burning starts in center of billets, typically resulting in a violent reaction
- Controlled burn locations combined with strategically placed vents increase the likelihood of non-violent burning reactions during SCO.

Phase 1 Pellet Only Configuration

Material 1 Pellets



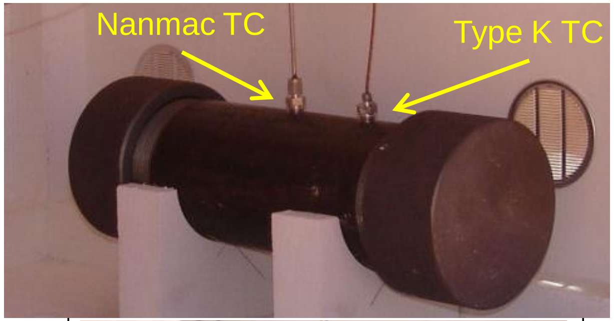


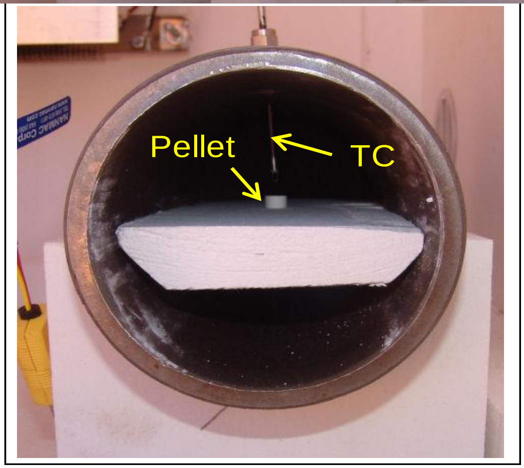
- Four SCO tests conducted with Material 1 to confirm results of prior study
  - Two tests with stack of bare 3 pellets
  - Two tests with 3 pellets in housing to show if confinement affects ignition temperature
    - 1 test with pellets in Ultem 1000 shroud
    - 1 test with pellets in 6061-T6 aluminum shroud
- Tests conducted to verify Material 1 will reliably self-ignite between 250-300 deg F

Phase 1 SCO Experimental Test Setup & Results

Pellet Only Configuration

- Tests placed in sealed pipe with two thermocouples used to measure temperature
  - Nanmac A4-53 fast response thermocouple over pellets
  - Type K standard response thermocouple to side of pellets
- Pipe was standard Schedule-40 4” dia. Steel pipe
- Pellets rested on insulation board roughly centered



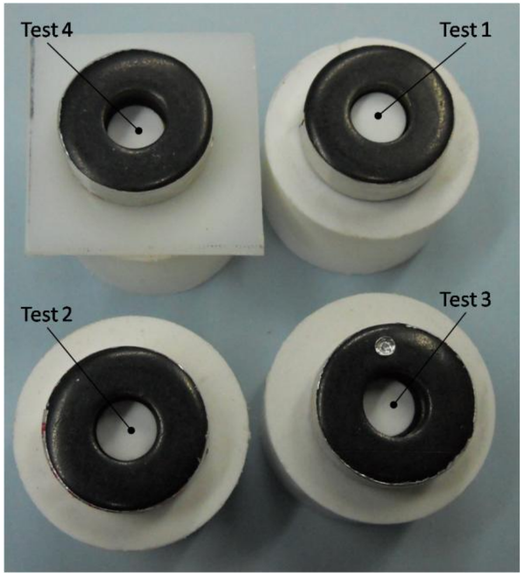


- Test 1 - 3 Bare Pellets →Reaction Temp = 294F
- Test 2 - 3 Bare Pellets →Reaction Temp = 292F
- Test 3 - 3 pellets in Ultem Shroud →Reaction Temp = 293F
- Test 4 - 3 pellets in Aluminum shroud →Reaction Temp = 300F

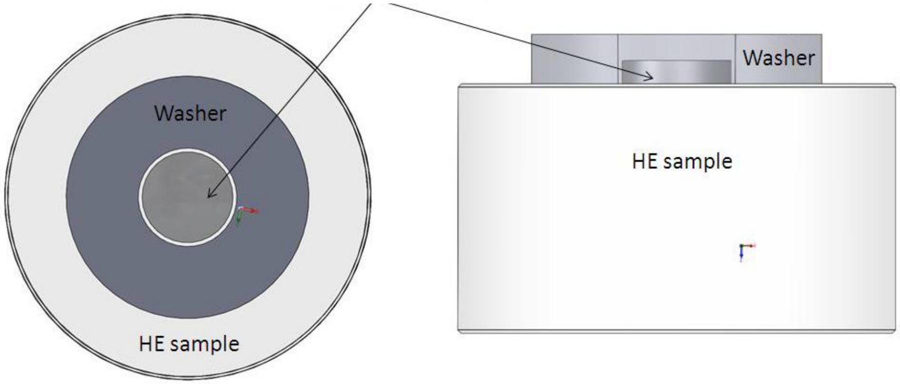
In all cases Material 1 completely consumed

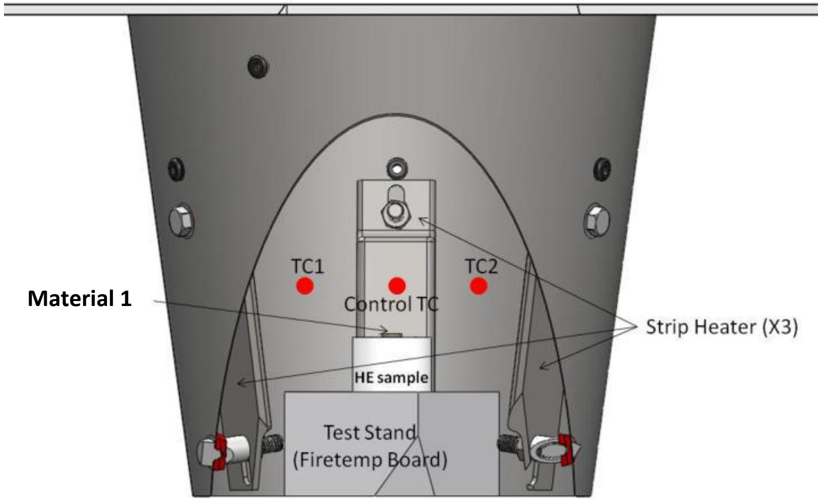
Phase 1 SCO Experimental Test Setup
Pellets with Explosive Configuration

- Next series of tests (5-14) were to see if Material 1 could start a surface burn in an explosive sample.
- Steel washer placed around each pellet(s) to provide some confinement for the Material 1 pellet
- PBXN-9 Samples place on pedestal made from insulation board



Material 1 Pellets (9.6x1.8mm)

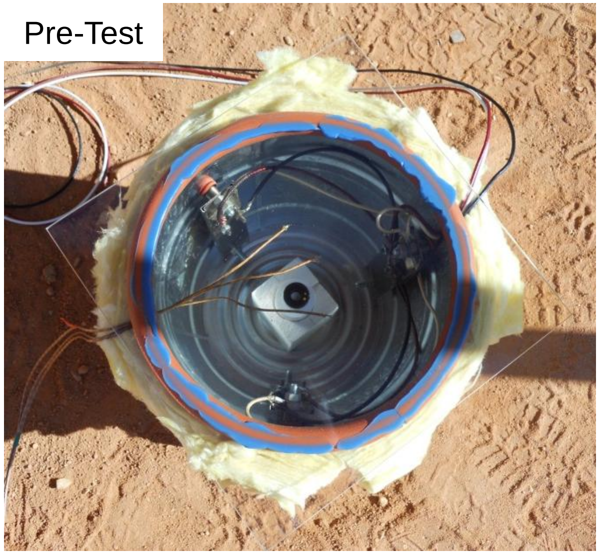




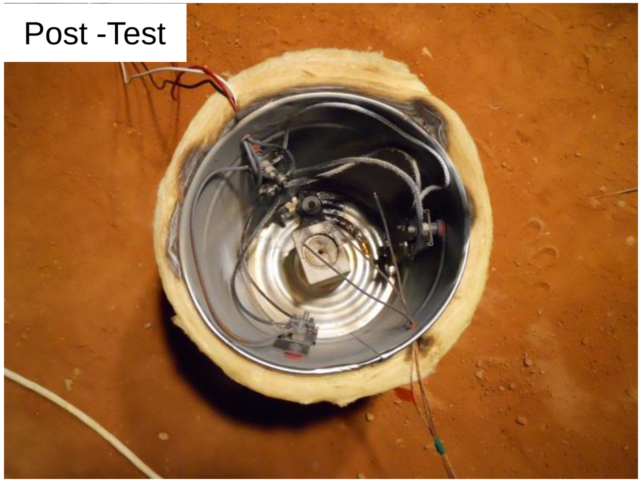
PHASE 1: PELLET TO EXPLOSIVE BURN TRANSFER CONFIGURATION AND TEST RESULTS -N-9

- For tests 5-8 Material 1 pellets failed to ignite. The N-9 sample cooked off first
  - Test 5 → 3 Pellets on Bare PBXN-9 sample
  - Test 6 → 1 Pellet on Bare PBXN-9 Sample
  - Test 7 → 1 pellet on Bare PBXN-9 Sample with aluminized tape
  - Test 8 → 1 pellet on Bare PBXN-9 sample with 0.10” HDPE
- After several match tests (take match to pellet) it was determined the batch of Material 1 was no longer usable
- Material 1 was proven to be severely hygroscopic and had not sealed properly
- Original batch of Material 1 was discarded and replaced with fresh material
- New material was stored double bagged with desiccant to ensure viability

Pre-Test

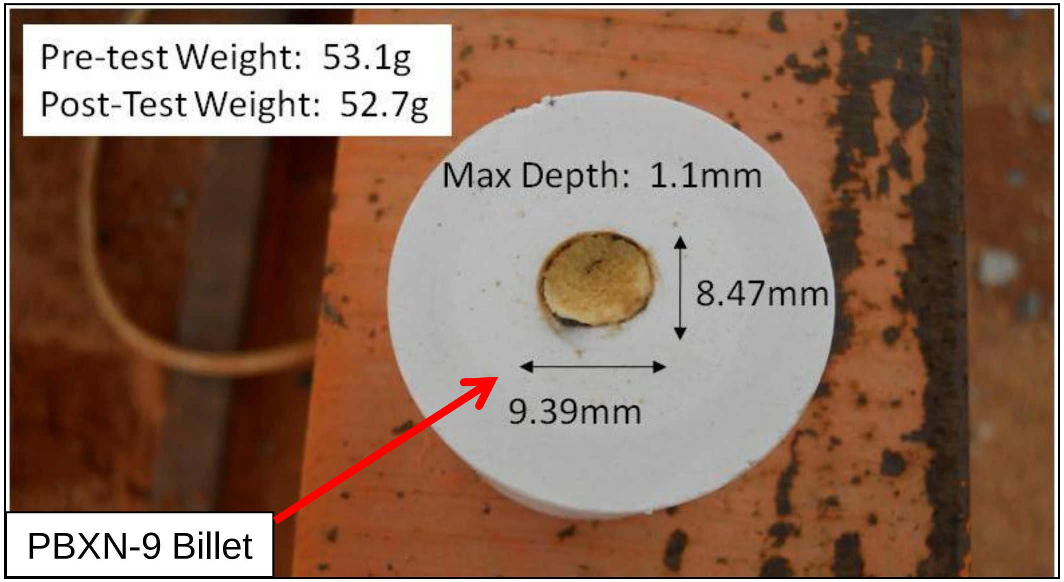


Post -Test



PHASE 1: PELLET TO EXPLOSIVE BURN TRANSFER CONFIGURATION AND TEST RESULTS -N-9

- Two additional SCO tests showed that Material 1 could be ignited:
  - Test 9 – 3 pellets on PBXN-9 → Reaction @ 296F
  - Test 10 – 3 pellets on PBXN-9 → Reaction @ 286F
  - In Tests 9 & 10, Material 1 reacted, but did not have the heat output to sustain a burn in unconfined PBXN-9

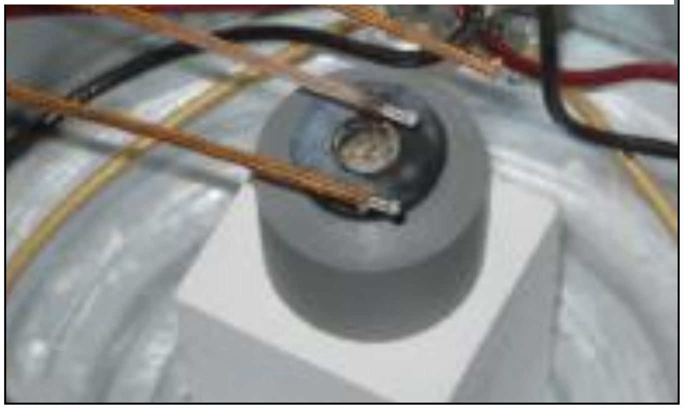


PHASE 1: PELLET TO EXPLOSIVE BURN TRANSFER CONFIGURATION AND TEST RESULTS –PAX-2A and PAX-42

- Test 11
  - 1 Bare Pellet on Bare PAX-2A→No Reaction
- Test 12
  - 1 Bare Pellet on Bare PAX-2A with aluminized tape → No reaction
- Test 13 –
  - **1 Bare Pellet on Bare PAX-42→ Reaction at 288F**
  - **Successful Sequence of reaction. Sustainer material fully consuming PAX-42**
- Test 14
  - 1 Bare Pellet on Bare PAX-42 with **aluminized tape** → Reaction at 289F - PAX-42 sample not consumed

Test 13 → Pellet ignites and consumes PAX-42

Test 14 → Pellet ignites but does not consume PAX-42



Phase 1 Experimental SCO Test Summary

Test #	Pellets	Explosive	Pellet Confinement	Barrier	Reaction Temp (F)	Reaction Description
1	3	None	None	None	294	Pellets burned
2	3	None	None	None	292	Pellets burned
3	3	None	Ultem 1000	None	293	Pellets Burned
4	3	None	6061-T6	None	300	Pellets burned
5	3	PBXN-9	Steel washer	None	-	Pellets failed to ignite
6	1	PBXN-9	Steel washer	None	-	Pellets failed to ignite
7	1	PBXN-9	Steel washer	Aluminized tape	-	Pellets failed to ignite
8	1	PBXN-9	Steel washer	0.1” HDPE	-	Pellets failed to ignite
9	3	PBXN-9	Steel washer	None	286	Pellets burned
10	3	PBXN-9	Steel washer	None	296	Pellets burned
11	1	PAX-2A	Steel washer	None	-	Pellets failed to ignite
12	1	PAX-2A	Steel washer	Aluminized tape	-	Pellets failed to ignite
13	1	PAX-42	Steel washer	None	288	Pellet burned, consuming PAX-42
14	1	PAX-42	Steel washer	Aluminized tape	289	Pellet burned, but PAX-42 did not

Phase 1 Conclusions

- Material 1 did not cause sustained burn in multiple explosive formulations
  - Material 1 hydroscopic nature limited storage life, even when sealed with desiccant
- New pyrotechnic formulation needed
  - A commercially available material has not been identified that can meet requirements
  - Material needs to self-initiate between 250-300F
  - Must have flame output that will sustain burn in explosive

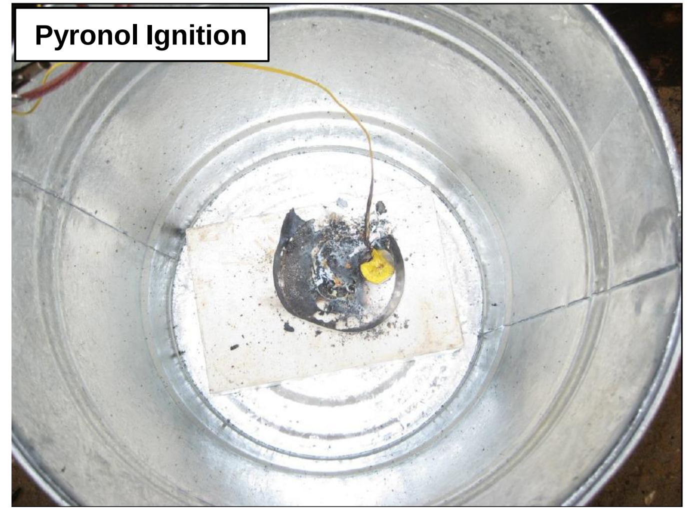
Phase 2: A Two Component Pyrotechnic Design Technical Approach

- A two-part solution will now be pursued
  - Pyrotechnic Igniter (Material 2A) will start to burn and ignite a sustainer (Material 2B)
  - Sustainer (Material 2B) will ignite explosive
- Material 2A
  - Researching "first fire" pyrotechnic materials that reliably cookoff within necessary temperature ranges
  - Promising materials will be tested later this summer
- Material 2B
  - Thermite formulation selected based on test data from Navy Countermine System Program
  - Material 2B has a flame temperature ~4500F (more than twice Material 1)

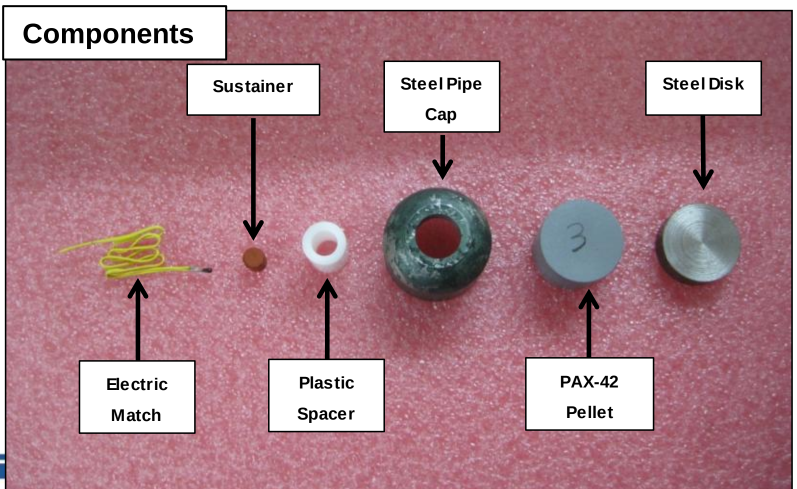
Phase 2 - Sustainer Output Test Setup & Results

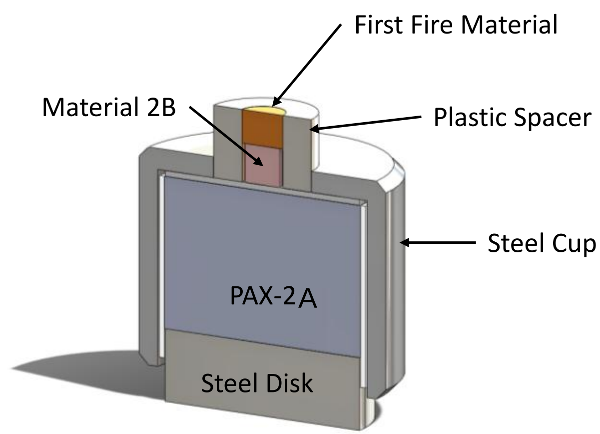
- Tests conducted at ambient temperature (~80F) for viability
- J Tek1 Electric match and FF30 used in place of igniter material
- Electric match sucessfully initiates sustainer Material 2B
- Steel and plastic components used to simulated expected confinement in an actual system

Pyronol Ignition



Components





Assembly

Phase 2 - Ambient Testing Results

- Initial testing with N-9 resulted in surface of billet charred, but no initiation transfer observed
  - Previous tests showed Material 1 can ignite PAX-42 with lower flame temperature if assembly temperature is elevated
    - Mat1 Flame Temp = 2100F
    - Mat2B Flame Temp = 4500F
  - Assumption is that Mat2B will easily ignite PAX-42 at elevated temperature
- Test will be repeated with assembly at elevated temperature

Future Work

- Elevated Temperature Sustainer Output Testing
  - Same Setup as Previously Shown
  - Sustainer Material Heated to 300 ° F Prior to Initiation
  - Additional HE Formulations: PAX-2A, PAX-3, PAX-30
  - Testing Scheduled for summer 2012
- Identification and Evaluation of Suitable Initiation Material
  - Initiation Temperature Range: 180 – 300 ° F
- Initiation Cook-off Testing
  - Combined Initiator & Sustainer Materials
    - Without HE: Test for Transfer Between Materials
    - With HE: Test for Transfer to HE

- BACK-UP