Twin Screw Processing of Black Powder w/ CMC binder

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Introduction

Current Manufacturing Process:

- Ball-mill Charcoal and Sulfur (pulverized rifle)
- Wheel mill ‘pulverized rifle’ with KNO_3 and H_20
- Press into cakes
- Granulate cakes via corning mill
- Sieved to appropriate classes (1 – 9)
- Glazed with graphite
- Dried (1 – 3 days) in dry house

Safety issues

- **High Personnel interaction with material**
- **High sensitivity to electrostatic discharge**
- **Pinch points**

Project Overview

Current risks associated with the manufacturing of black powder:

- Single Point Failure (SPF) condition exits
- Periodic incidents
  - Nov. 5, 1998 – Explosion on initial manufacturing process
  - Jan. 25, 2000 – Flash fire and explosion
  - November 1, 2001 – Detonation of 1,000 pounds of Clearshot
  - April 2006 – wild fire caused explosion

US Army, in conjunction with GOEX, Inc. and TCI, seek to provide a safer, more reliable process for manufacturing BP through the use of a twin screw extruder.

Project Overview

Picatinny Arsenal, NJ

2003, to mitigate these risks, U.S. Army Program Executive Officer for Ammunition (PEO Ammo) funded a foreign comparison test (FCT). TSE BP selected to be tested along with foreign sources

- Initial effort: show processability of a BP-type material through a TSE using a water soluble binder
  - January 2004, ~15 lb black powder substitute (BPS) produced
- Current effort: to provide a BPS with comparable performance characteristics as that of conventional BP using a water soluble binder
  - August 2006, RDECOM-ARDEC produced over 100 lb
  - As of today: 85 – 90% of performance criteria

Initial Effort

Rheology

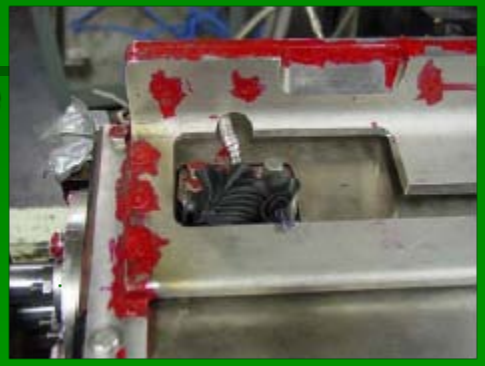
- shown that mil-spec formulation not processable
- a binder needed to increase ‘flowability’ of the formulation
  - Sodium CarboxyMethyl Cellulose (CMC) was chosen due to its ability to form a hydrogel that will be the carrier for the TSE formulation.

Components	Mil-Spec (wt %)	Live (wt %)	Live w/o CMC (wt %)
KNO_3	74 ± 2.0	71	74
Charcoal	15.6 ± 1.5	15	15.6
Sulfur	10.4 ± 2.0	10	10.4
CMC	--	4	--

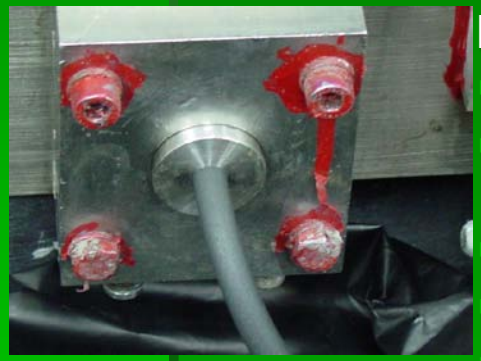
Initial Effort

Inert Runs

- Barrel leak was seen -- High wall slip condition caused a backup in the single screw section which increase internal barrel pressure



Remedies



Mechanical

- Die diameter increased (2/10” to 3/8”)
- Strengthen hydraulic piston holding power by increasing cylinder length
- Machine o-ring grooves into one of the barrel halves
- Relocated middle hydraulic cylinder to position after die
- Re-level machine from the ground up

Logistical

- Incorporate NaCl/KNO_3 thirty seconds after first pressure reading in Mix Zone 1 seen -- Decreased the formation of hydrogel

Current Efforts

Goal: to produce a BPS that has comparable performance to conventional BP

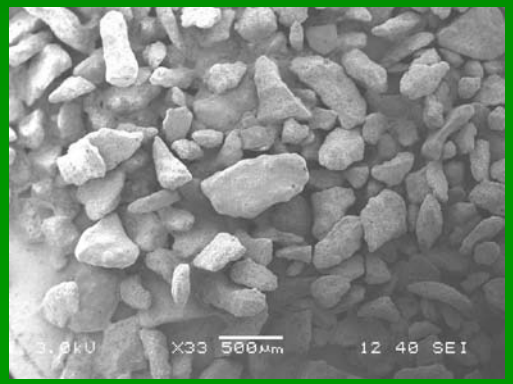
- Raw ingredient studies
- Modified processing parameters
- Pre- and Post-processing studies
  - Ball milling effects
  - Drying techniques
  - Pressing and corn milling effects
- Standardize testing procedures
- Benchmarking end items

Current Efforts

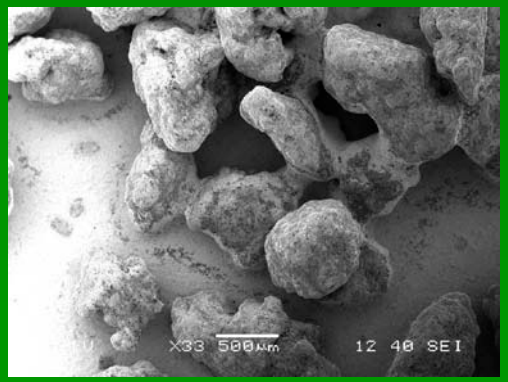
Raw Ingredient Studies:

- Material gathered from GOEX showed:

	Particle Size Distribution	
Material	**GOEX**	**TSE**
Preblend (pulverized rifle)	1 – 30 μm	Non ball milled: 1 – 200 μm Ball milled: 1 – 100 μm
Post processing BP	< 10 μm	~100 μm



Goex Class 7



TSE Class 5

Current Efforts

Modified Processing Parameters:

- Screw configuration
- Feed order
  - Relocate KNO_3 feed stream prior to introduction of H_2O
- Feed rates
  - Decrease H_2O from 4.3 lb/hr to 3.3 lb/hr

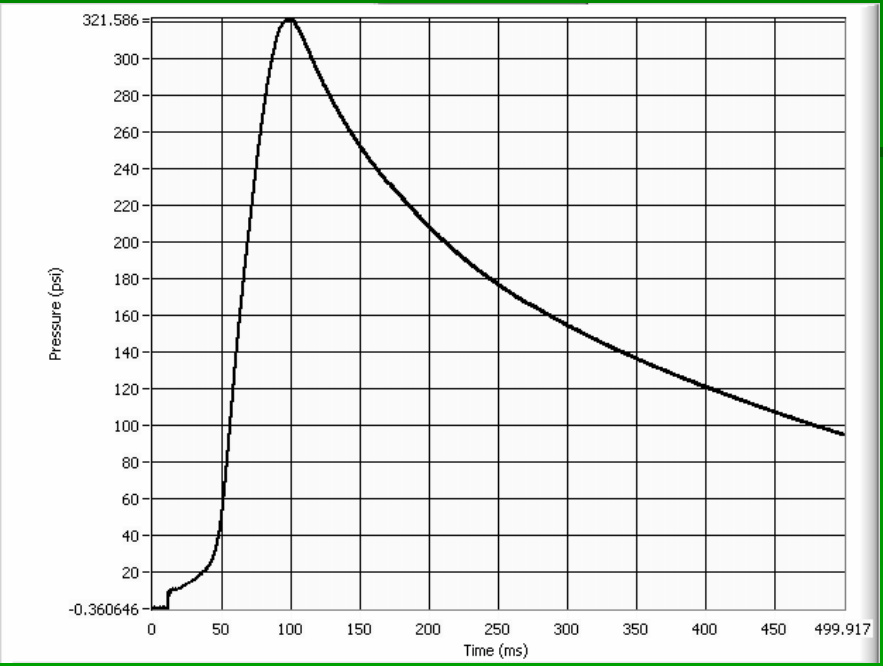
Twin Screw Extrusion of Black Powder w/ CMC Binder

Current Efforts

Drying Techniques:

- Steam table (~160ºF - 240ºF)
- 1 – 5 days
- Sulfur recrystallation effects
  - Crystalline modifications of Sulfur
    - Pre 205ºF – Rhombic
    - 205ºF to 246ºF – Monoclinic
    - 320ºF and above – Polymeric

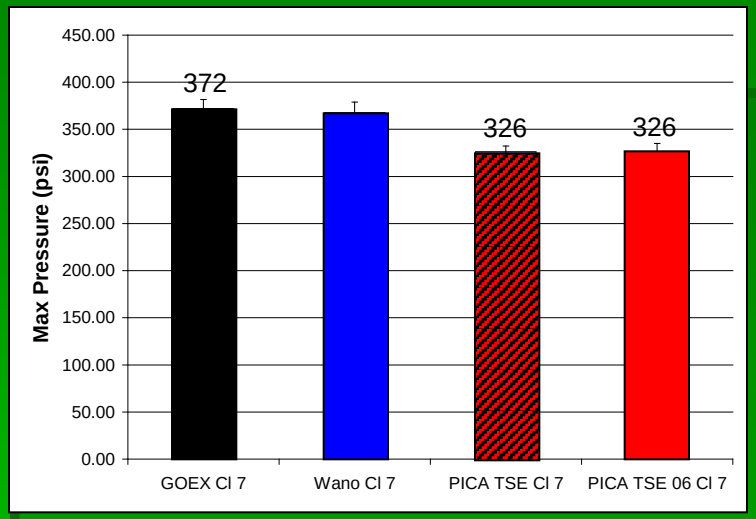
Testing – Closed Bomb



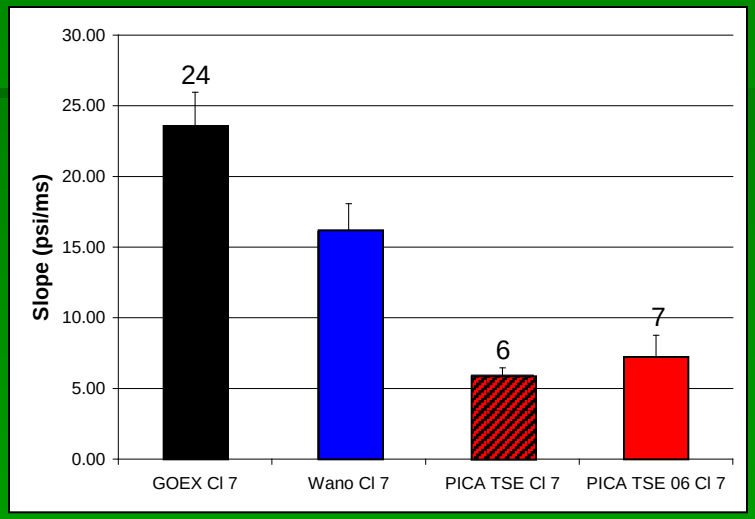
- Pressure vs. time data is collected
- Determines
  - Maximum pressure
  - Rise time (time from 10% to 90% of peak pressure)
  - Function time (time from t0 to peak pressure)
  - Slope (slope of curve from 10% to 90% of peak pressure)

Testing – Closed Bomb

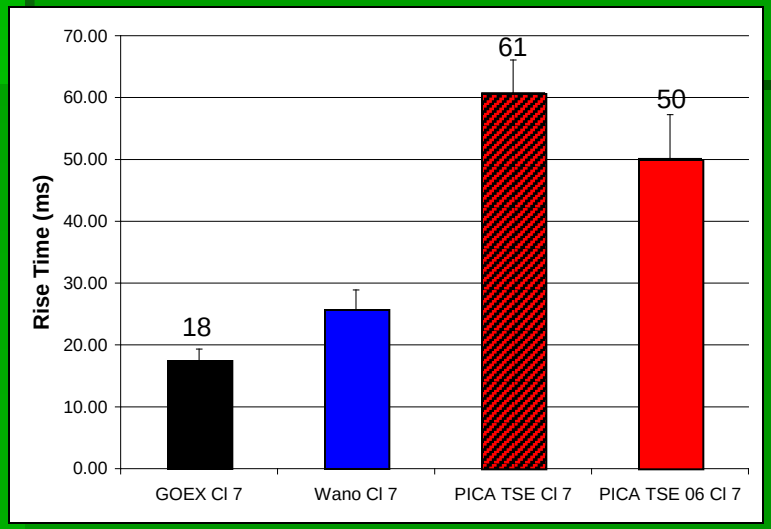
Maximum Pressure



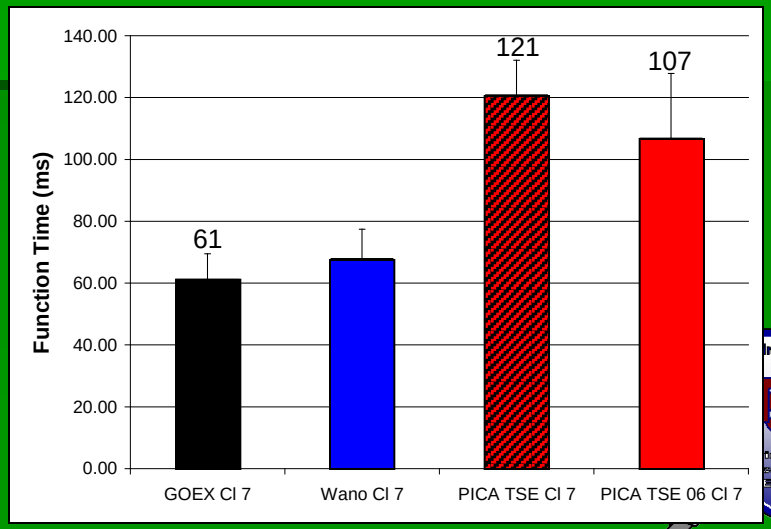
Slope



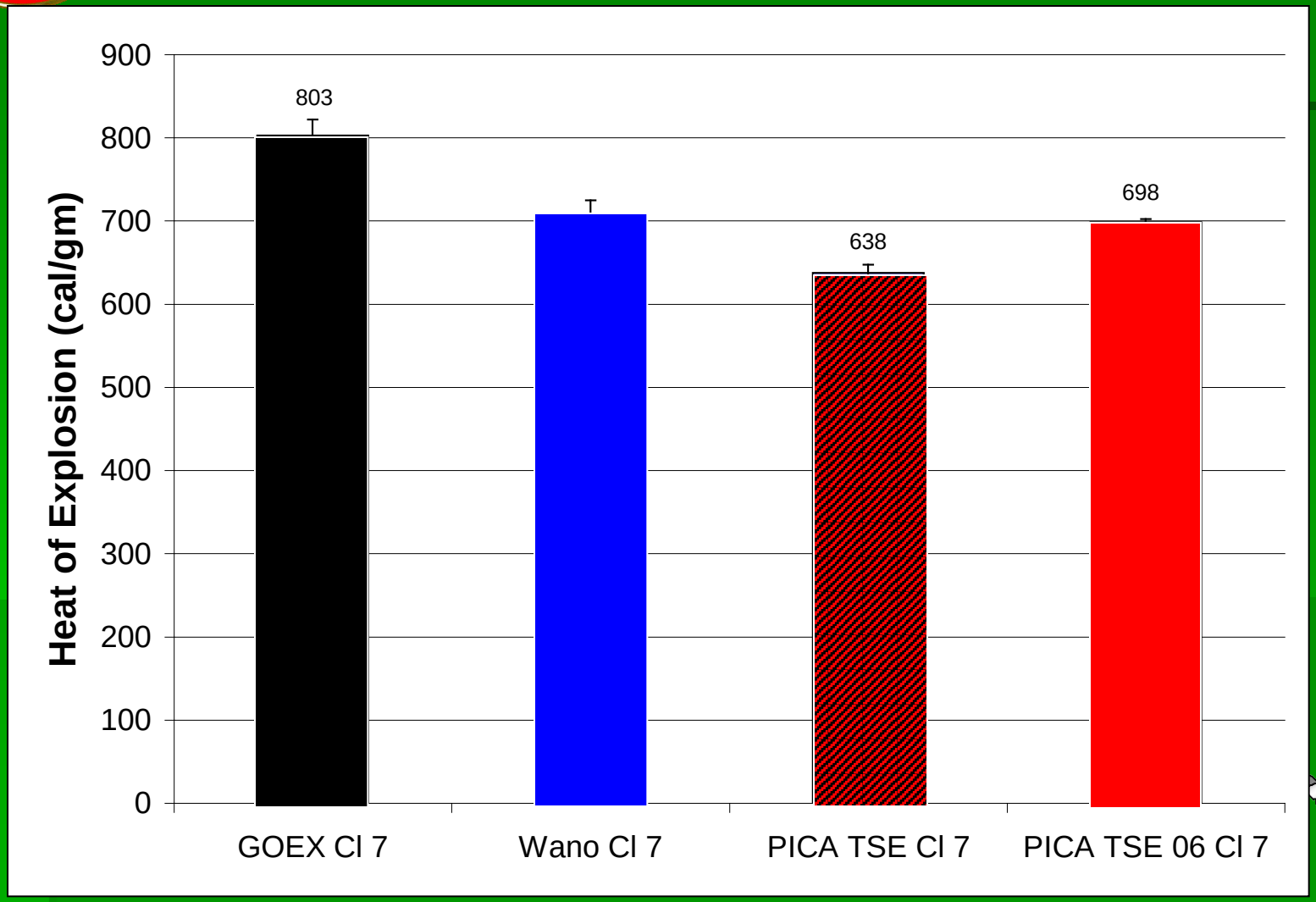
Rise Time



Function Time



Testing – Bomb Calorimetry



On going

- Current performance indicates 85 – 90%
- Quantify performance criteria for use in end items
  - Load TSE BP into hand held signal
- Further study drying techniques
- Increase shear on material through screw configuration
- Increase bulk density by increasing die pressure
- Modified energetic binder system