

RECENT DEVELOPMENTS IN MANUFACTURING OF PRIMERS BASED ON NANOENERGETIC COMPOSITES

Dr. Zac Doorenbos

Principal R&D Engineer

Innovative Materials and Processes, LLC

Rapid City, SD 57701



AGENDA

- Background
- Integrated Energetics Materials Processing
- Small Caliber Percussion Primers
- Medium Caliber Primers
- Conclusions

INNOVATIVE MATERIALS AND PROCESSES, LLC

IMP is a company focused on the development of new technologies in the area of nanomaterials, especially nanoenergetics. IMP R&D activities also include the synthesis and processing of advanced ceramic materials, and specialized pyrotechnic systems. The company was established in 1999.

Key Personnel

- *Dr. Jan Puszynski – President*
- *Dr. Zac Doorenbos – Principal R&D Engineer*
- *Mr. Matt Puszynski – R&D Specialist*

BACKGROUND

Energetic nanothermite research supports an effort to replace compounds containing heavy metals (lead) in current military applications,

for example:

- percussion primers (small and medium caliber),
- electric primers (electric matches, pyrotechnics),
- low energy initiators (LEI).

Several metastable energetic nanocomposites, also known as metastable interstitial composites (MIC) or nanothermites (superthermites) were identified as the potential substitutes for currently used lead styphnate or lead thiocyanate.

Aluminum-based nanothermites (aluminum-metal oxide systems) are of particular interest in terms of their energetic characteristics.

Examples: Al-MoO₃, Al-WO₃, Al-CuO and Al-Bi₂O₃.

BACKGROUND

Distinct characteristics of nanothermites:

1. Nanothermites consist of at least two reacting components (fuel and oxidizer);
2. Combustion reaction rate of nanothermite mixtures strongly depends on reactant's particle size and particle intermixing;
3. Energy release can be tuned by choice of the reactive components.

Characteristics 2 and 3 are relevant specifically to the percussion primer and other types of initiators

BACKGROUND

Thermodynamic properties of selected thermite reactions

Thermite reaction	Q [cal/g]	Q [cal/cm ³]	Gas generation 1 atm, [g gas /g mixture]	T _{ad} [K]
$2\text{Al} + \text{Fe}_2\text{O}_3 \rightarrow 2\text{Fe} + \text{Al}_2\text{O}_3$	945.4	3947	0.0784	3135
$2\text{Al} + \text{Bi}_2\text{O}_3 \rightarrow 2\text{Bi} + \text{Al}_2\text{O}_3$	505.1	3638	0.894	3319
$2\text{Al} + \text{MoO}_3 \rightarrow \text{Mo} + \text{Al}_2\text{O}_3$	1124	4279	0.2473	3688
$2\text{Al} + \text{WO}_3 \rightarrow \text{W} + \text{Al}_2\text{O}_3$	696.4	3801	0.1463	3253
$2\text{Al} + 3\text{CuO} \rightarrow 3\text{Cu} + \text{Al}_2\text{O}_3$	974.1	4976	0.3431	2843

BACKGROUND

Nanothermites can be difficult to process safely due to their sensitivity to friction and electrostatic discharge (ESD).

A typical small scale preparation of such mixtures involves mixing of nano-size reactant powders in an inert solvent (wet mixing).

After sufficient mixing of a slurry, the solvent is evaporated and the nanothermite is recovered, resulting in a loose powder.

Any handling of loose nanothermite powder must be carried out with **extreme caution**.

Nanothermite System	ESD ignition energy (mJ)
Al-Fe ₂ O ₃ , powder	0.113
Al-MoO ₃ , powder	0.050
Al-Bi ₂ O ₃ , powder	0.001
Al-Bi ₂ O ₃ , granule	1.5

MAJOR PROCESSING CHALLENGES

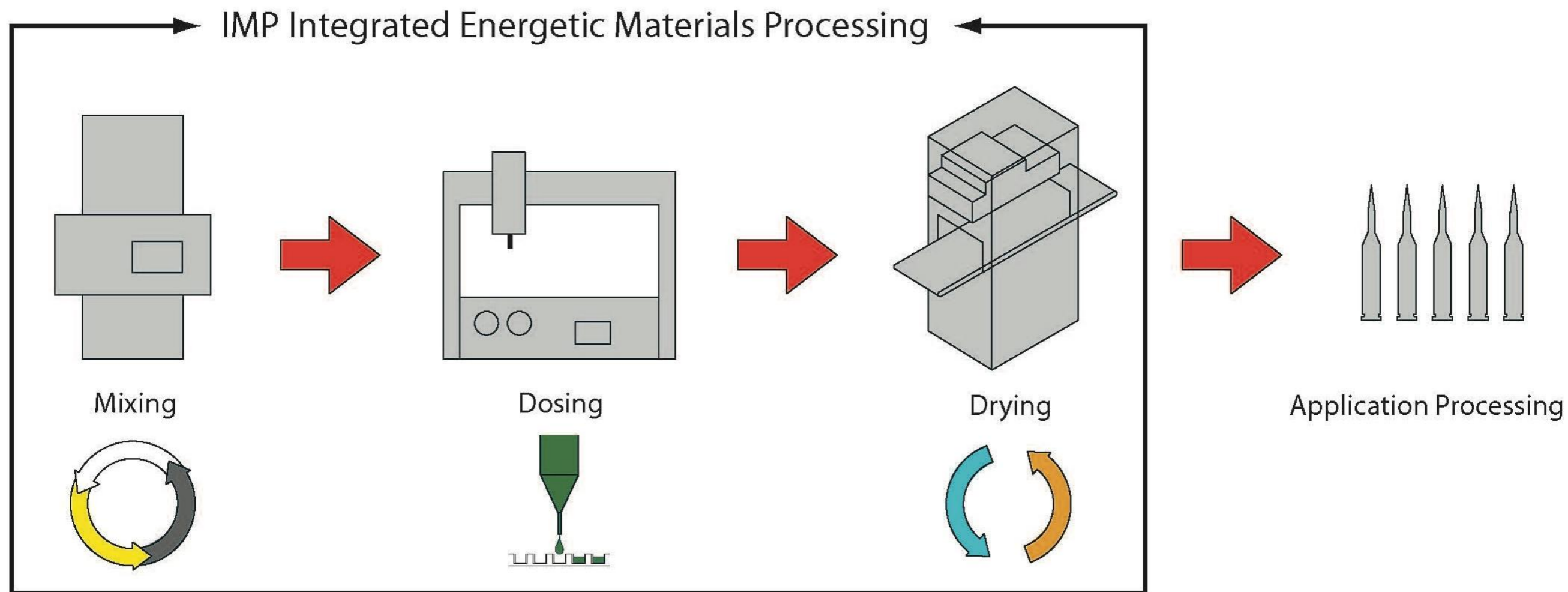
- Processing in organic flammable solvents;
- Batch processing of small quantities;
- Stratification of reactants due to the difference in densities;
- Processing and loading of ultrafine extremely ESD sensitive powders;
- High reactivity of nanosize aluminum with moisture;
- Inherent brittleness of consolidate nanothermite.

CRITICAL DESIGN IMPROVEMENTS

- Mixing flexibility of multi-component systems consisting of nanopowders and additives with different densities for energetic output tunability;
- Use of water as a processing solvent;
- Semi-continuous mixing system with an automated loading system.

A new mixing process¹ of the nanothermite components in a water slurry was developed by the Innovative Materials and Processes LLC. Based on this water based processing an integrated energetic materials processing system has been developed.

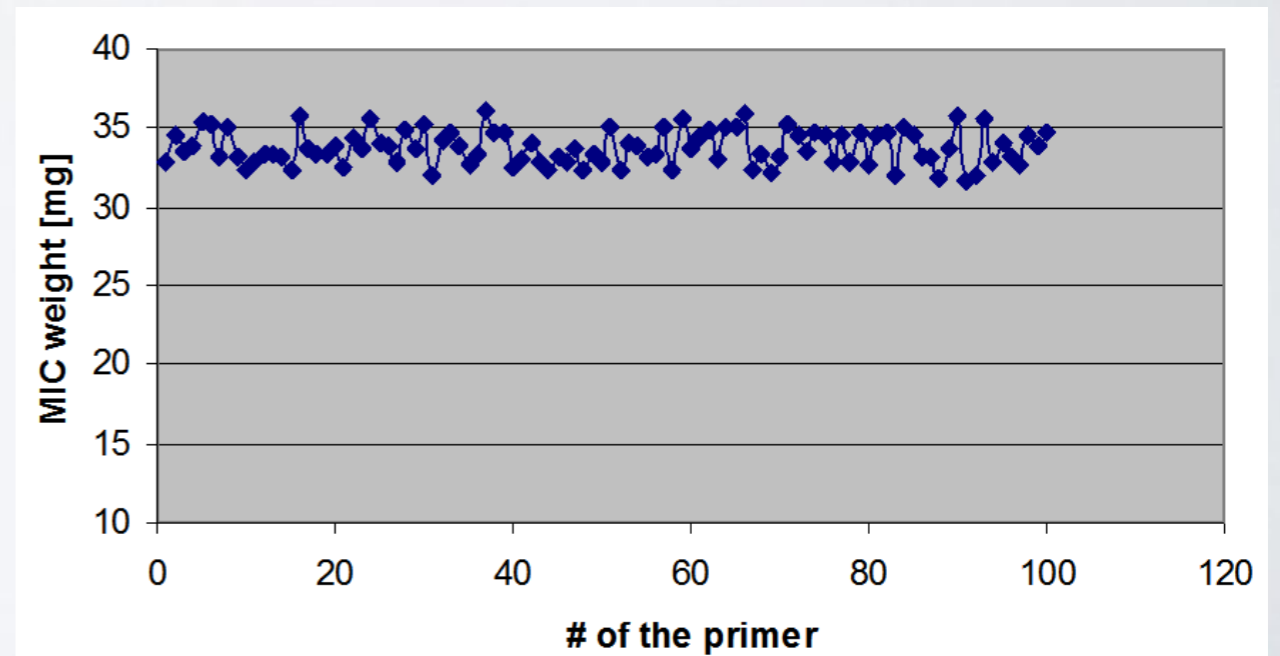
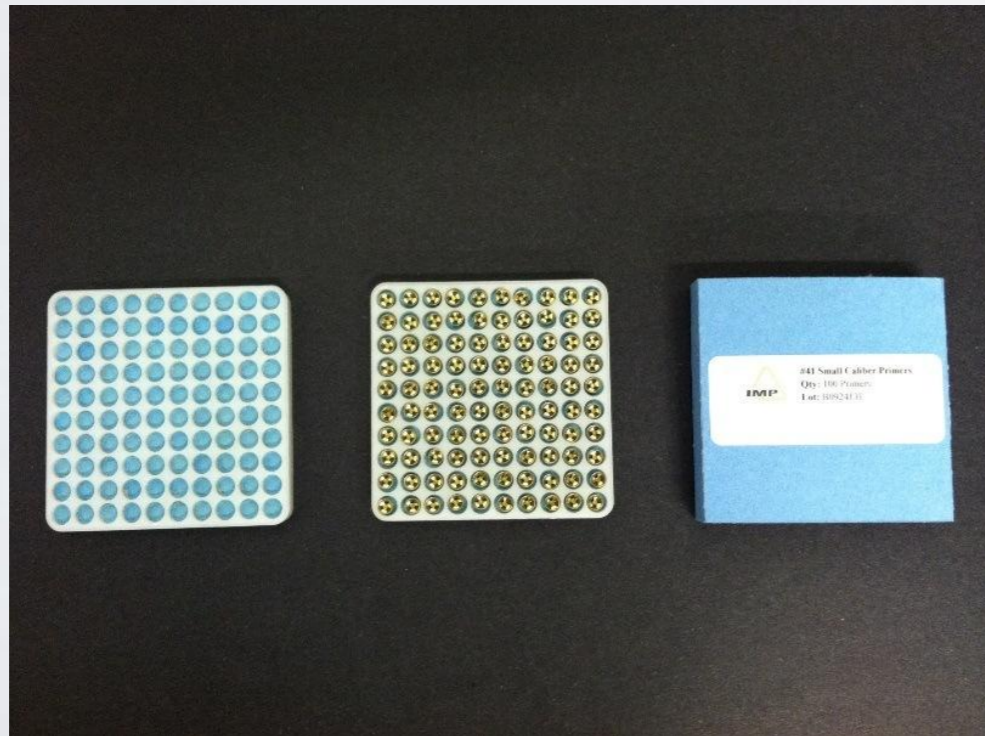
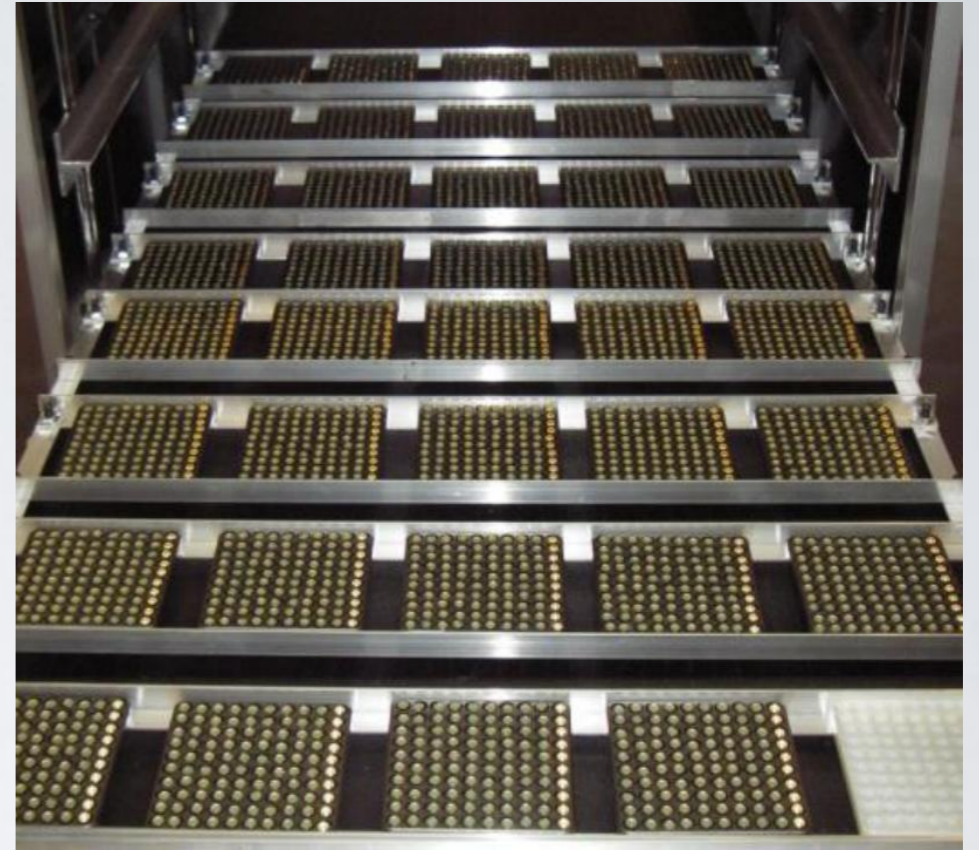
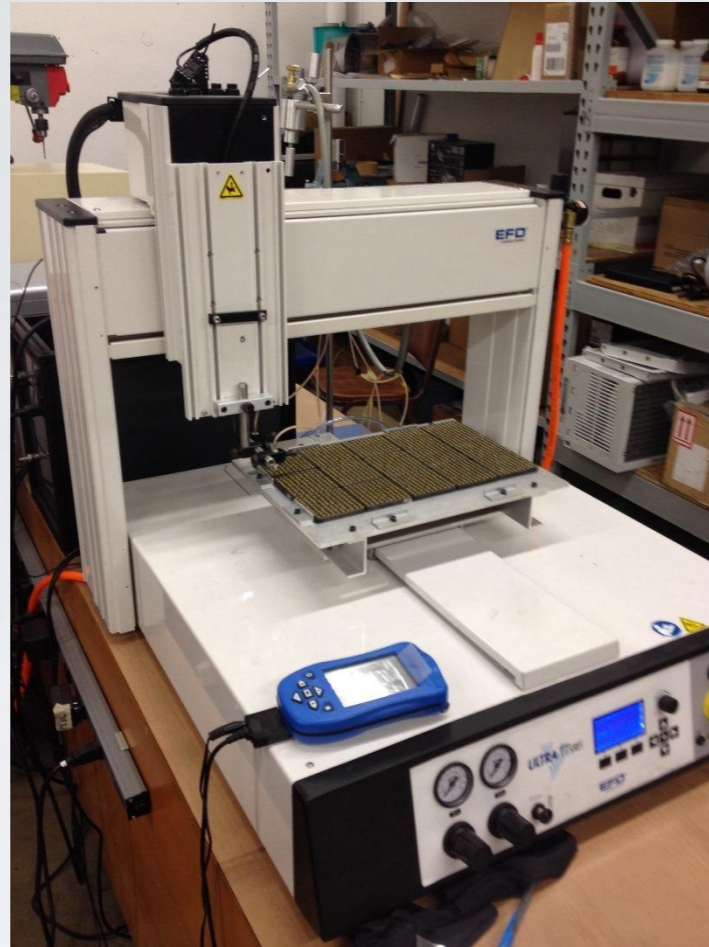
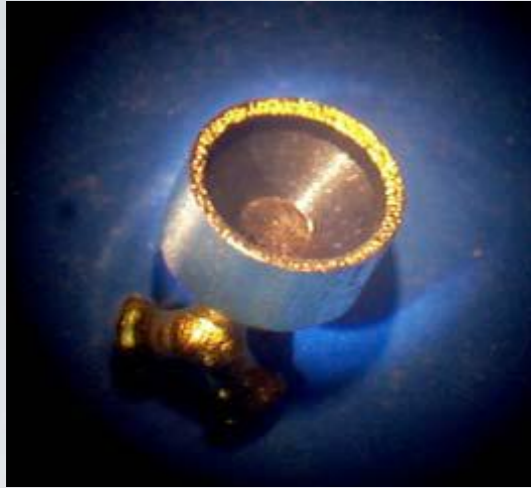
¹U.S. Patent 7,670,446: J.A. Puszynski, J.J. Swiatkiewicz and M. Bichay, “Wet Processing and Loading of Percussion Primers Based on Metastable Nanoenergetic Composites”



INTEGRATED ENERGETIC MATERIALS PROCESSING SYSTEM

SMALL CALIBER PERCUSSION PRIMERS

- Automated water based loading of up to 3000 primers per hour;
- High level of tunability through the addition of non-water soluble additives (e.g. Tetrazene);
- Tested with both #41 and M42 small caliber primers;

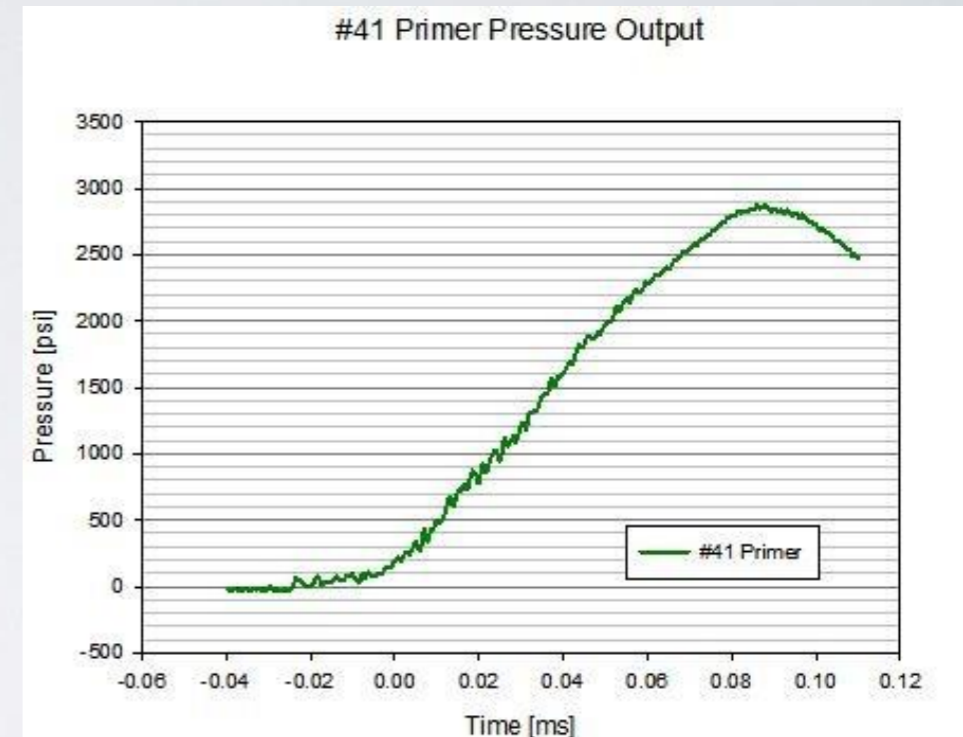


$$\mu = 33.7 \text{ mg} \pm 1.3 \text{ mg}$$

Primer Type	Average Projectile Velocity (ft/sec)	Average t_{action} (ms)
Standard #41	2723±26	0.960±0.031
Nanothermite	2701±14	0.944±0.009

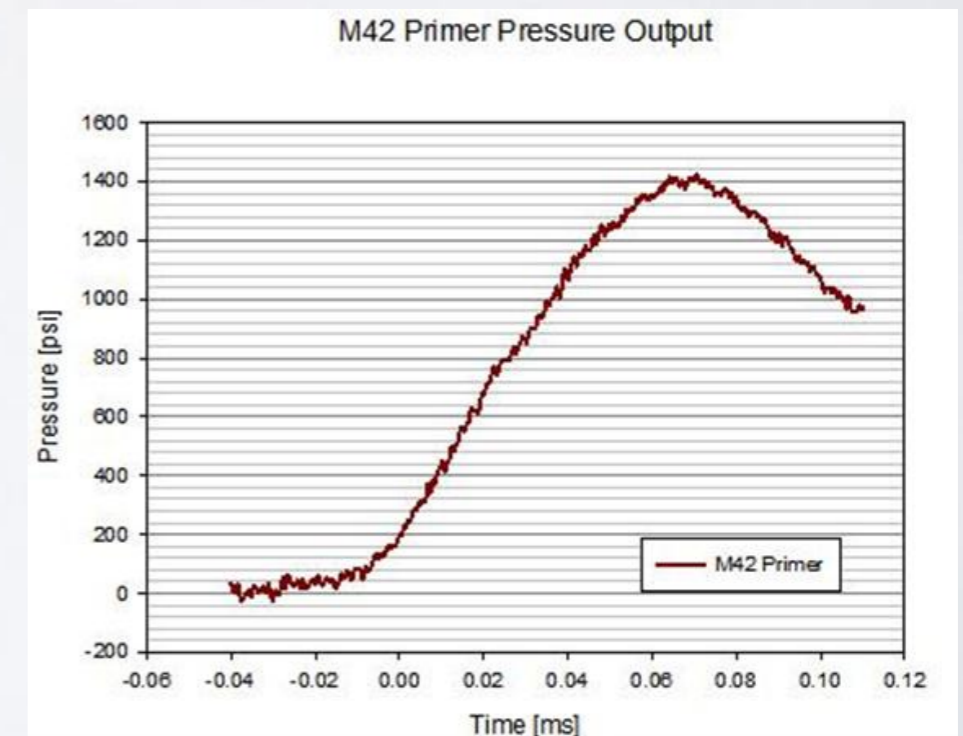
#41 Neyer Results
Sample Size: 30 primers
Ball Weight: 3.94 oz

μ_H	4.76 in
σ	0.3 in



M42 Neyer Results
Sample Size: 30 primers
Ball Weight: 1.94 oz

μ_H	4.44 in
σ	0.74 in



MEDIUM CALIBER PRIMERS

- Use of same automated system for:
 - Carbon Bridge Formation
 - Loading of nanothermite composite material
- PA520 and M52A3B1 medium caliber electric primers;

Cartridge action time results for the PA520 nanothermite composite primers (50 samples were tested at each temperature) (Mil-Spec: $\mu + 3\sigma < 4$ ms).

PA520 MIC Composite Primers in LW30mm Round			
Temperature	Mean Action Time [ms]	Std Dev [ms]	Mean + 3 σ [ms]
Ambient (70°F)	2.44	0.132	2.83
High (160°F)	1.81	0.054	1.97
Low (-65°F)	2.65	0.248	3.65

CONCLUSIONS

- Nanothermite composite materials can be used as a replacement for lead based material in primer applications;
- Environmental testing has shown that the reactants from Al- Fe_2O_3 and Al- Bi_2O_3 nanothermites have low potential for water transport and there is limited toxicity of these materials in water;
- Innovative Materials and Processes, LLC has developed an Integrated Automated Energetic Materials Processing system for loading both small and medium caliber primers;
- The IAEMP system is very flexible and can be easily scaled up for higher production requirements.

QUESTIONS

Dr. Zac Doorenbos

Principal R&D Engineer

Innovative Materials and Processes, LLC

Rapid City, SD

Phone: 605-484-3434

Email: doorenbos@imp-co.com

