New Pressed Explosives With Improved Insensitive Munitions Characteristics

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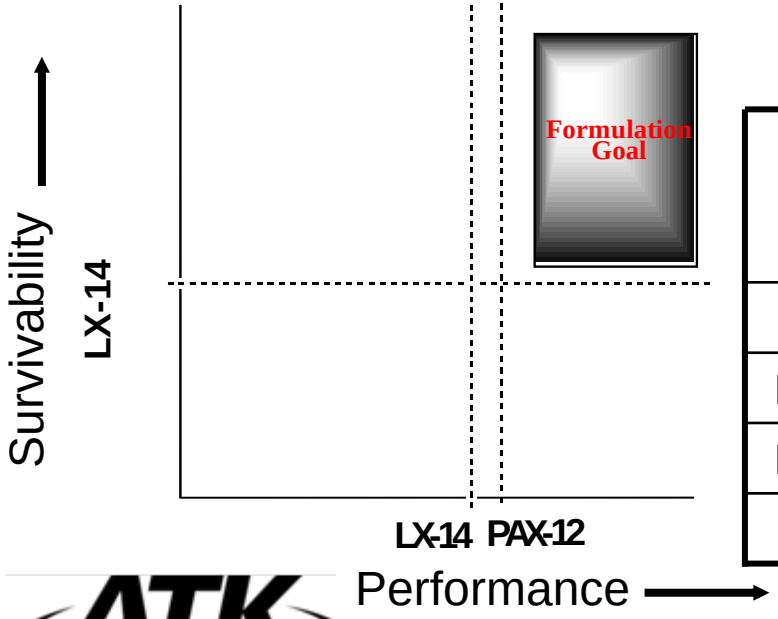
Outline

- Objective
- Bullet Impact Mitigation
- Cook-off Mitigation
- Summary

Objectives

Develop an explosive which meets the following criteria:

- **Armor piercing with enhanced blast capability > PAX-12**
- **Improved IM response over LX-14**
  - Measured by bullet impact sensitivity and cook-off

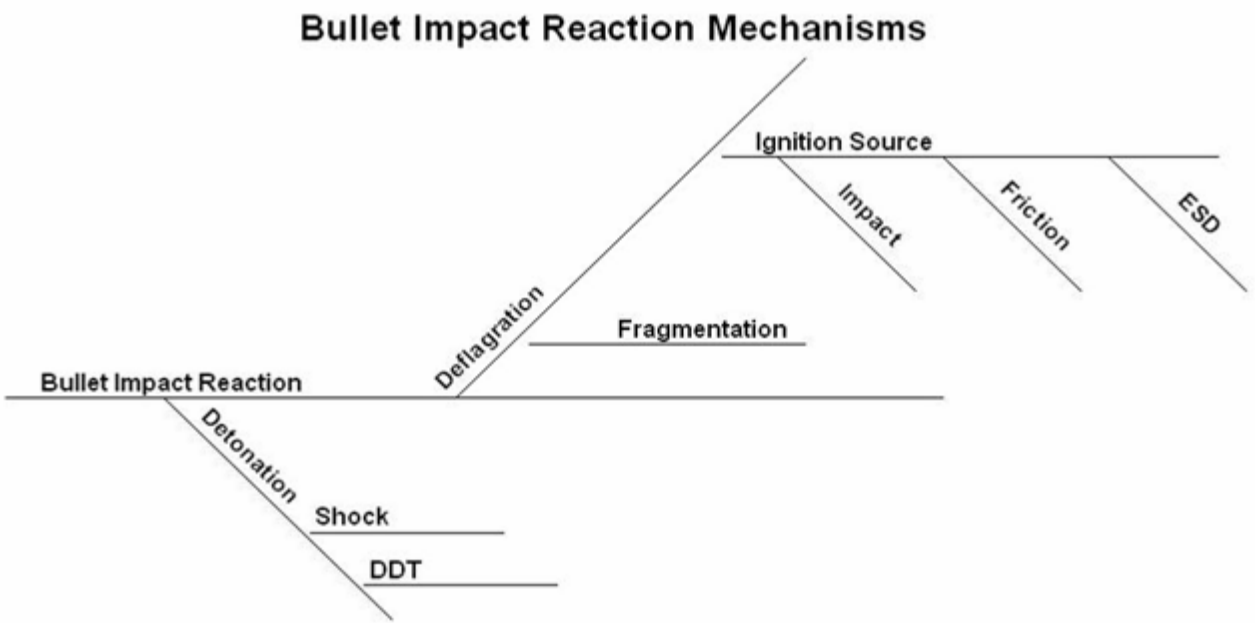


Selected Theoretical Values

	Total Enrgy (kJ/cc)	CJ Pressure (kbar)	Vel. (km/s)	V/Vo @6.5 (kJ/cc)	99% TMD (g/cc)
CL-20	12.4	463	9.82	10.8	2.02
PAX-11	11.4	423	9.38	9.88	1.96
PAX-12	10.9	391	9.16	9.33	1.92
LX-14	10.1	353	8.98	8.47	1.84

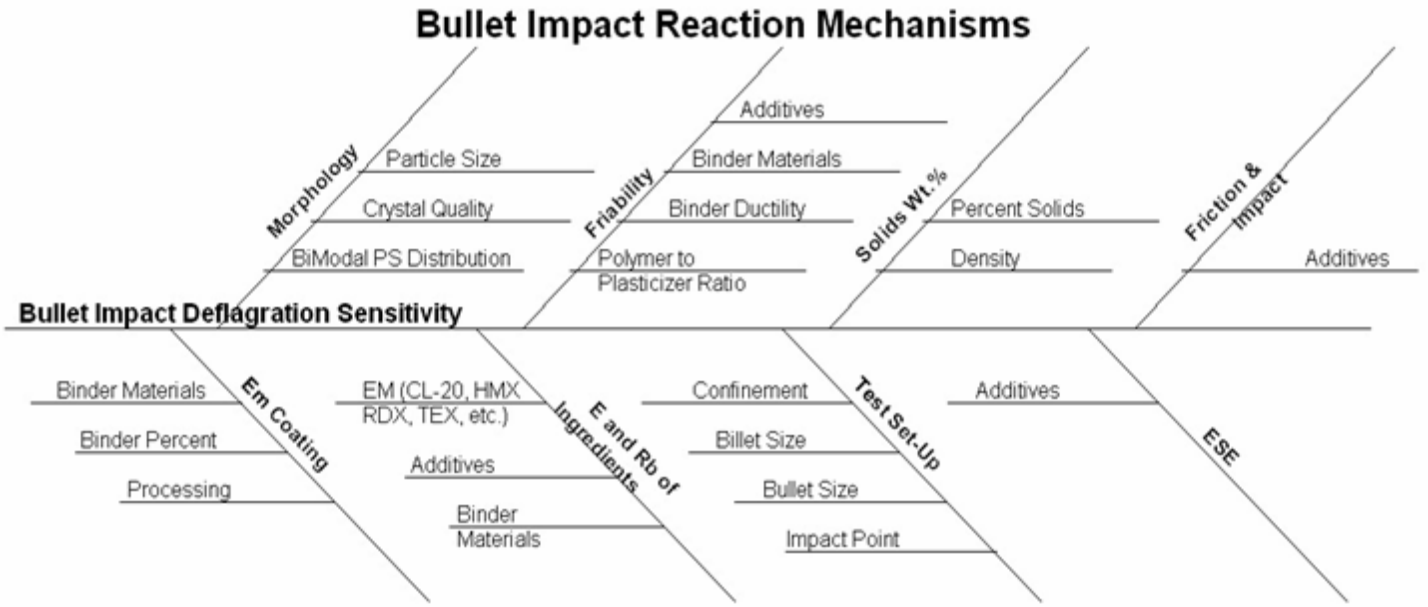
Bullet Impact Sensitivity

- **Goal: Find root cause for an adverse reaction in bullet impact testing**
  - Determine the reaction mechanism in bullet impact response
    - Utilize pressure gauges, high speed video, witness plates



Observation

- **Testing showed that *deflagration* was the most common response to bullet impact for the explosives tested**
  - A fishbone diagram was built to understand variables leading to that response
  - Subsequent formulation work focused on these variables in order to minimize the response



Typical Test Set-Up

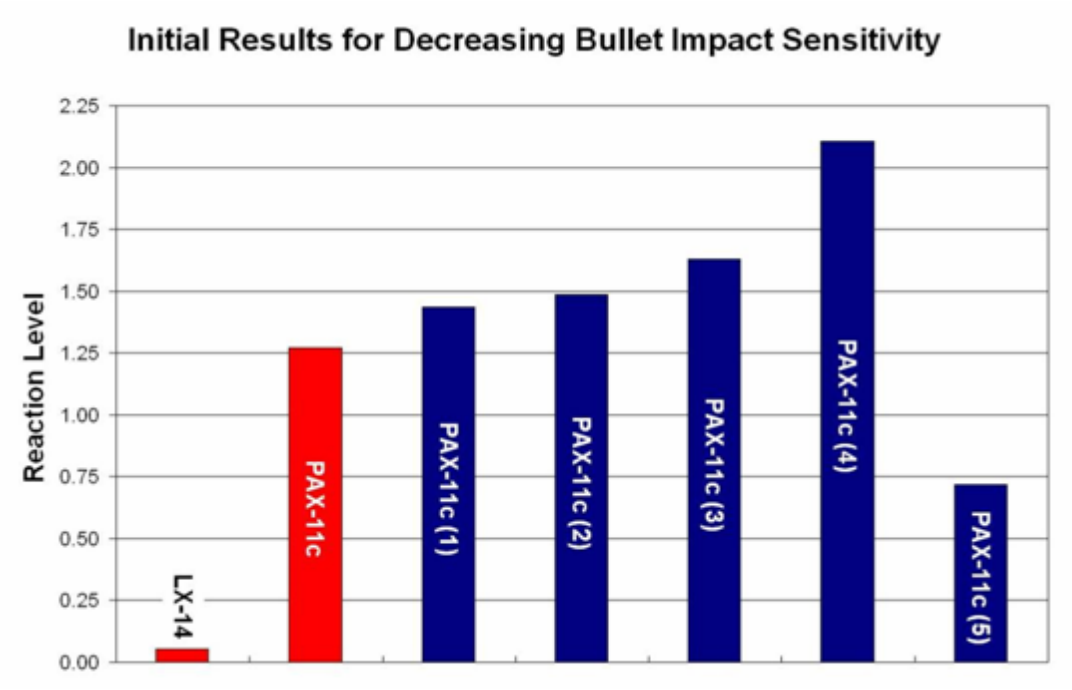
Overall View

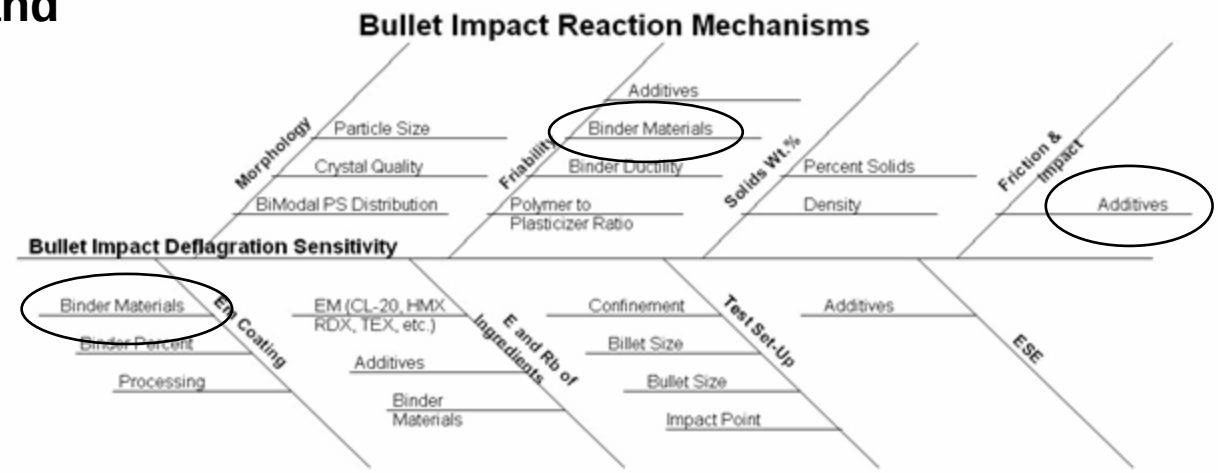
- **Data acquisition**
  - Pressure
  - High speed digital video
  - Both were very useful!

Close-Up Of Billet

Early Bullet Impact Results

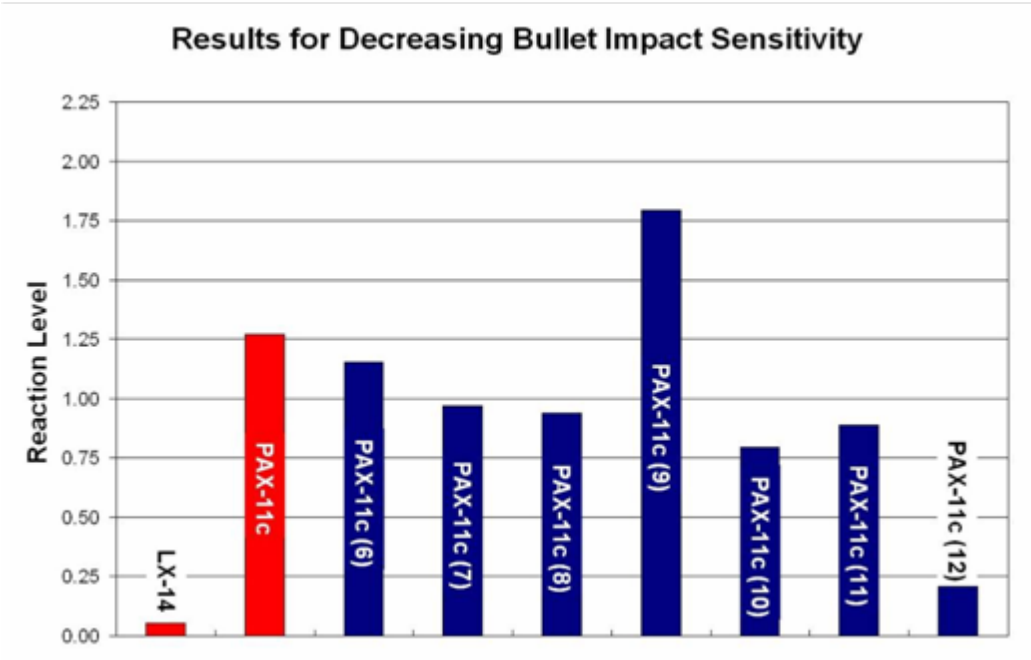
- **Reaction level of LX-14 is significantly lower than PAX-11c baseline formulation**
- **Formulation variants 1 – 3 focused on additives that would reduce friction**
  - Initial results and additives were not promising
- **Formulation 4 & 5 focused on friability and EM coating by adjusting binder materials and polymer to plasticizer ratio**
  - Formulation 5 worked
  - Formulation 4 didn't!
  - Lessons were learned for future iterations

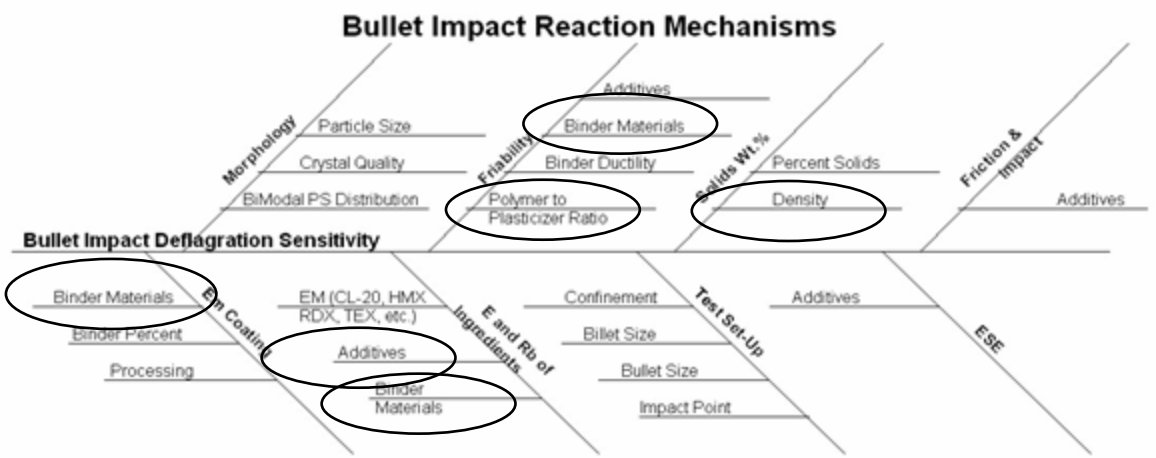




Bullet Impact Tests

- **Testing continued by checking multiple variables**
- **Most of the formulation variants (6 – 12) were less reactive**
  - Friability
    - Polymer/plasticizer
    - Binder system
  - Energy
  - Burn rate of ingredients
  - Coating quality
- **Formulation 12: Combined best ingredients from previous testing**

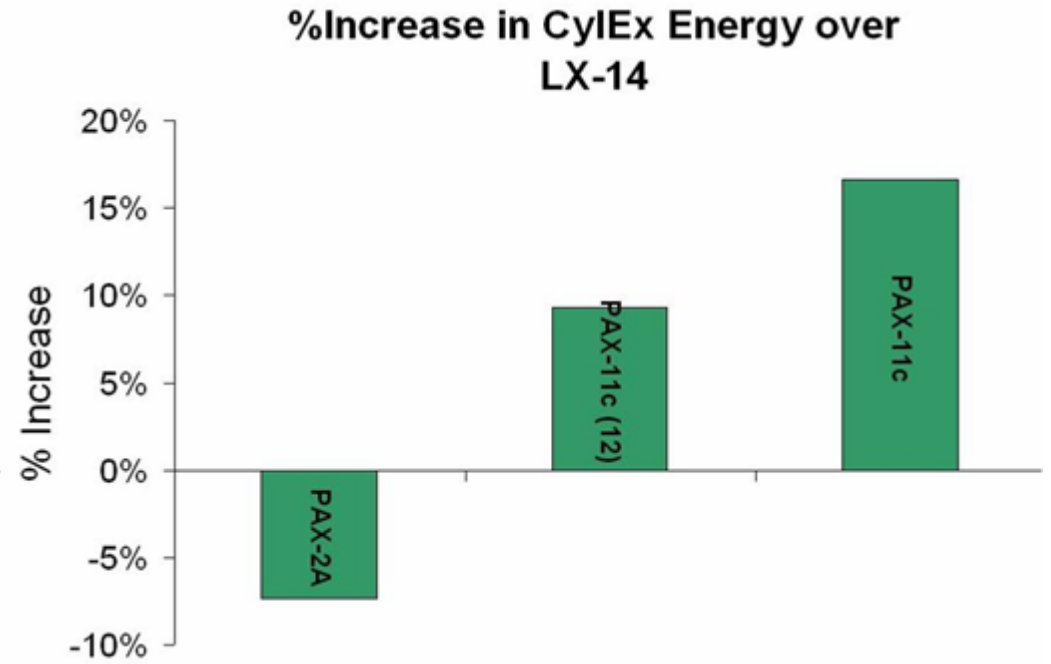




Bullet Impact vs Performance

Predicted Performance

- PAX-11 (12) has a predicted C-J Pressure that is 12% greater than LX-14
- Cylinder Expansion Energy is nearly 10% greater



Summary of Bullet Impact Sensitivity

- LX-14 is only marginally less sensitive than PAX-11c (12) to bullet impact

Theoretical Values

	LX-14	PAX-11c (12)	PAX-11c
C-J Pressure (GPa)	34.43	38.69	42.33
Cylinder Expansion (kJ/cc)	8.47	9.26	9.88
BI Peak Pressure (psi)	0.46	0.88	2.82
BI Pressure Impulse (psi-s)	0.054	0.28	1.27

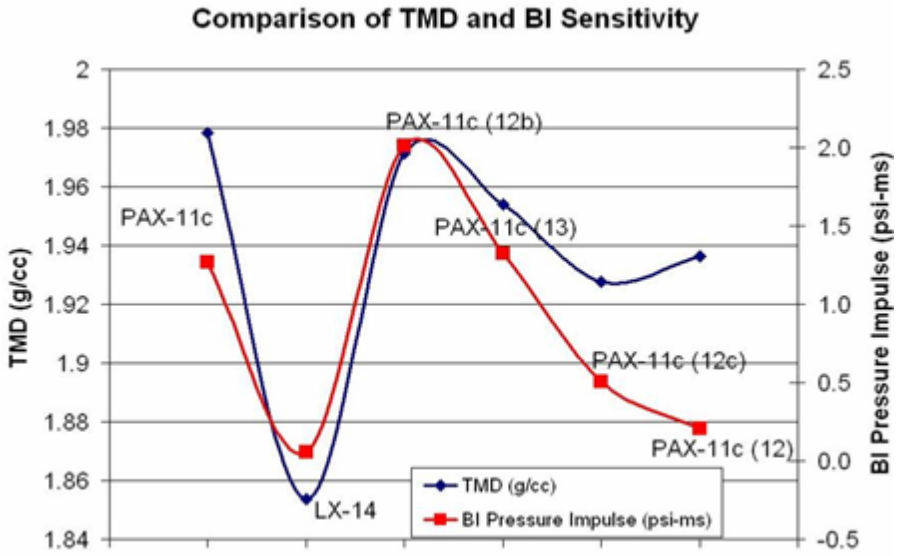
Correlation With BI Sensitivity

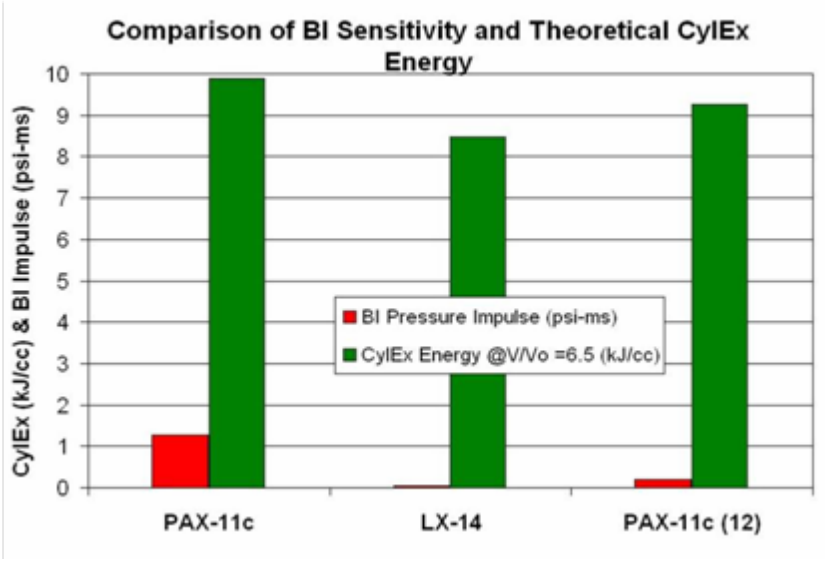
Comparison with Material TMD and BI Sensitivity

- Both PAX-11c and LX-14 follow very closely a TMD and BI response trend
- PAX-11c (12) allows an increase in material TMD with a minimal increase in BI sensitivity

Comparison with TMD, BI and Cylinder Expansion Energy

- PAX-11c (12) offers a positive balance between energy and sensitivity
  - – High CylEx Energy
  - – Low BI Sensitivity



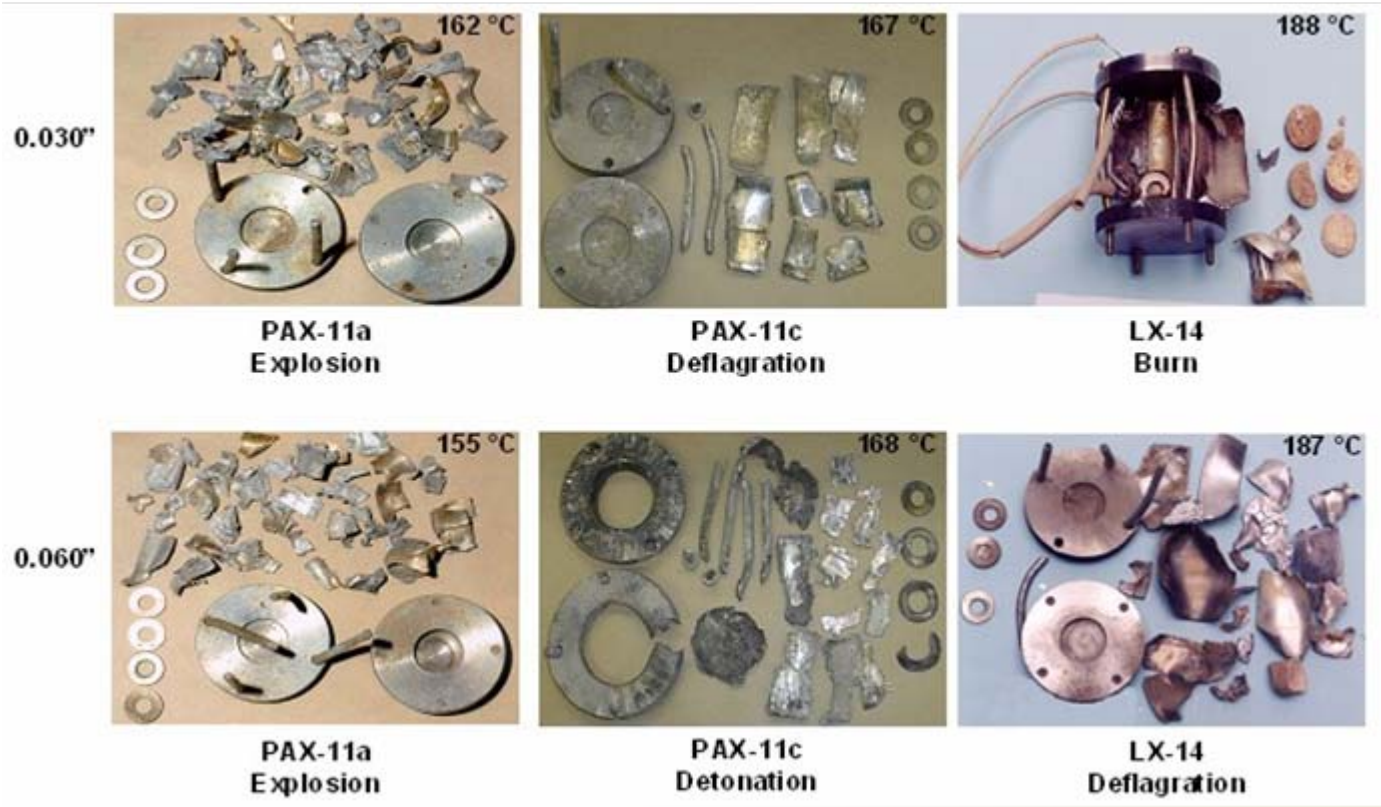


BI Test Results

- Pe
- Si
  11
- Re

Cook-Off Sensitivity

- **Goal: Determine the root cause for an adverse reaction in cook-off testing**
  - Approach: Develop a better understanding of the reaction mechanism in cook-off testing
    - Utilize Variable Confinement Cookoff Test (VCCT)
    - Measure
      - » Reaction Temperature
      - » Reaction Violence



Cook Off Sensitivity

Variable Confinement Cookoff Testing (VCCT) used to screen candidates

- **VCCT testing was performed on PAX-11c (12) gave excellent results**
  - A deflagration through 0.075 inches of confinement
  - Test at 0.075 inches of confinement was repeated with same excellent result

Confinement	Reaction Temp	Time to Reaction	Reaction Level
0.030 (in.)	173 °C	24.17 hrs	Press. Rupture
0.045 (in.)	173 °C	23.88 hrs	Deflagration
0.060 (in.)	173 °C	23.82 hrs	Deflagration
0.075 (in.)	176 °C	24.62 hrs	Deflagration

Cook Off: LX-14 vs PAX-11c

	LX-14	PAX-11c (12)	PAX-11c
VCCT @ 0.030" Confinement	188°C Burn	173°C Pressure Rupture	167°C Deflagration
VCCT @ 0.075" Confinement	186°C Detonation	176°C Deflagration	168°C Detonation

Results

- **PAX-11c (12)**
  - Nothing more severe than deflagration in VCCT
  - Little improvement in intrinsic thermal stability as measured in DSC
- **LX-14**
  - Detonation reaction at 0.075" confinement

0.030"

PAX-11c (12)

PAX-11c Deflagration

LX-14 Burn

0.060"

PAX-11c (12)

PAX-11c Detonation

LX-14 Deflagration

Advances In Cook Off

- **Lessons learned by the ARDEC/ATK team have been applied to a new metalized formulation line with very promising results**

Advances In Cook-Off

- **New explosive with significantly improved reaction violence also had a surprisingly high cook-off temperature**
  - Approximately 30°F higher than baseline composition
  - Often high cook off temperature equals a violent reaction!

VCCT Results (Ignition Temperature °F)					
	Wall Thickness (in)				
Formulation	***0.030***	***0.045***	***0.060***	***0.075***	***0.090***
LX-14	Burn (370°F)	Burn (369°F)	Deflagration (369°F)	Detonation (367°F)	NA
Baseline Metalized	Burn (364°F)	Pressure Rupture (366°F)	Partial Detonation (366°F)	Detonation (365°F)	Detonation (364°F)
New Metalized	Burn (394°F)	Pressure Rupture (395°F)	Pressure Rupture (392°F)	Deflagration (394°F)	Deflagration (398°F)

Summary

Bullet Impact Sensitivity

- Bullet impact sensitivity measured by pressure impulse of a high energy explosive was greatly reduced by following an organized systematic approach
- An understanding of bullet impact sensitivity can lead to improvements in other formulations

Cookoff Sensitivity

- Using the same formulation that led to reduced bullet impact sensitivity a significant reduction as achieved in cookoff sensitivity
- The methodology developed in reducing cook-off violence to an initial formulation line was applied to a new formulation line with excellent results!
- *Similar changes to other formulations may lead to similar improvements*