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

Demonstration of an Environmentally Benign Composition for the M209 Shotshell Primer

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AGENDA

Introduction

Initial Development at CCDC

Safety Approval at Manufacturer

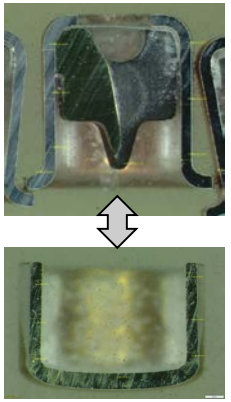
Mixing and Primer Assembly

Conclusions

HAND HELD SIGNALS (HHS)

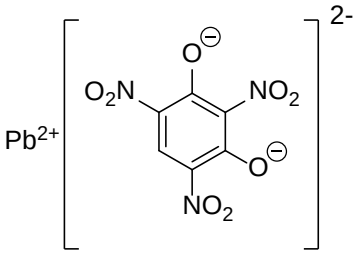
- HHS suite of armaments employ the 209 shotshell primer
  - HHS is used in training and combat for visible smoke and illuminant signatures
  - 209 primer embedded in end of rocket barrel; end cap contains firing pin

Cup in cup design

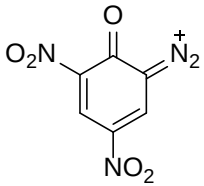


PROBLEMS WITH 209 PRIMERS

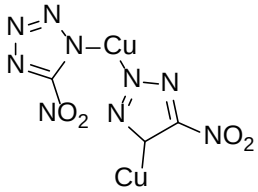
- Most primers use toxic lead styphnate as active explosive ingredient
- Manufacturers have lead-free primer options based on DDNP
  - Inadequate for military, due to vacuum thermal stability and cold performance
- An alternate lead-free explosive is copper (I) 5-nitrotetrazole (DBX-1)
  - Proven out in detonators, CAD/PAD devices and more
  - Relatively unexplored in primers
  - A possible drop-in production replacement; no major capital investment needed



Lead styphnate



Diazodinitrophenol
(DDNP)



DBX-1

ALTERNATE, LEAD-FREE PRIMER MIX

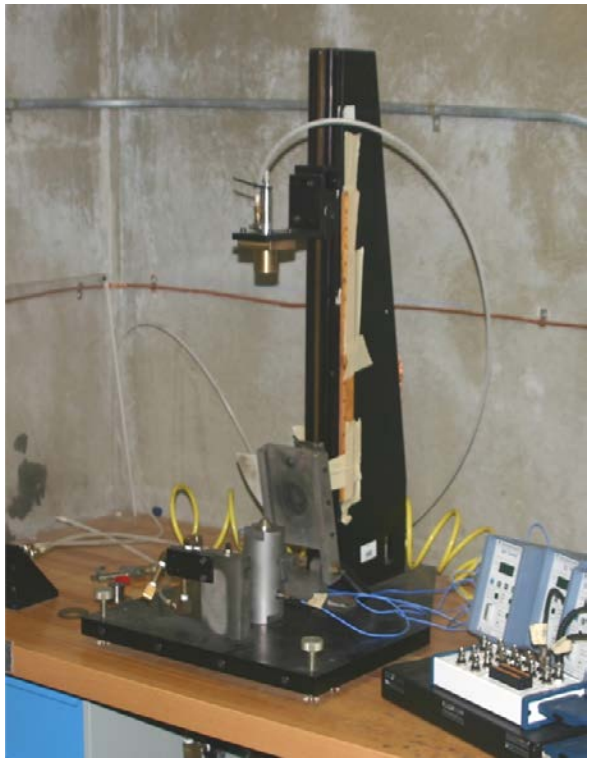
- **Established a new primer mix based on DBX-1 to replace lead**
  - Also replaced:
    - barium nitrate (toxicity problem)
    - antimony sulfide (supply problem)
  - Mixed 10 gram batches at CCDC by hand
  - Loaded into primer bits with custom tooling
    - One at a time!

Ingredient	Function	Wt. %
Potassium nitrate (KNO_3)	Oxidizer	61.4
DBX-1	**Active ingredient**	**17**
Aluminum powder	Fuel, slag generator	10
Tetrazene	Sensitizer, gas generator	5.7
Boron carbide (B_4C)	Abrasive, frictionator	5.7
Celvol 523	Binder	0.2

Csernica, C.; Oyler, K.; Sabatini, J.; Mehta, N. (2016). “Non-Toxic Primer Mix.” US Patent no. US9409830B1.

TESTING PRIMERS AT CCDC

- **CCDC primers tested against commercial primers with 3.94 oz ball in 1.8 cc partially vented bomb.**
  - Setup allows output and sensitivity testing simultaneously
  - CCDC and commercial primers have comparable sensitivity profile



Lot	Hbar (in.)	σ (in.)	Hbar + 4σ (in.)	Hbar - 2σ (in.)	P_{peak} (psi)
CCDC	3.32	0.22	4.20	2.88	**3,962**
Commercial	3.05	0.21	3.89	2.63	2,594

TRANSITION TO INDUSTRY

- **Need to scale up primer mix at high volume producer**
- **Improve manufacturability**
  - –Scale up primer assembly process
  - –Transition from one at a time to integrated plate process
- **Transitioned to NGIS out of Lake City Army Ammunition Plant (LCAAP)**
  - –First needed safety approval to handle DBX-1
    - Chemical compatibility testing with common chemicals
    - Wet and dry Impact/Friction/ESD testing on DBX-1
    - 7-day water stability study
  - –Invent plate process
  - –Fabricate and test 209 primers with alternate mix

DBX-1 SENSITIVITY STUDIES

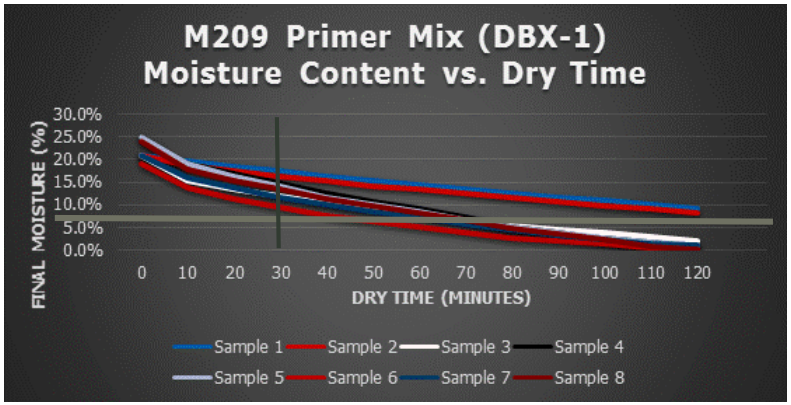
	Test	DBX-1/ water	Lead Styphnate/ water	Color Change	DBX-1/IPA
0 Hrs	Impact, cm	1	11	no	1
	Friction, N	<4	18		<4
	ESD, J	<0.0013	0.0013		<0.0013
24 Hrs	Impact, cm	1	11	no	
	Friction, N	<4	31		
	ESD, J	<0.0013	0.0013		
48 Hrs	Impact, cm	11	7	no	
	Friction, N	<4	11		
	ESD, J	<0.0013	<0.0013		
72 Hrs	Impact, cm	3.5	3.5	no	
	Friction, N	<4	18		
	ESD, J	<0.0013	0.0013		
96 Hrs	Impact, cm	3.5	3.5	no	
	Friction, N	<4	11		
	ESD, J	<0.0013	0.0013		
120 Hrs	Impact, cm	7	>100	no	
	Friction, N	<4	53		
	ESD, J	0.0013	<0.0013		
144 Hrs	Impact, cm	11	>100	no	
	Friction, N	<4	53		
	ESD, J	<0.0013	<0.0013		
168 Hrs	Impact, cm	7	>100	no	
	Friction, N	<4	53		
	ESD, J	<0.0013	<0.0013		

MOISTURE CONTENT AND SENSITIVITY

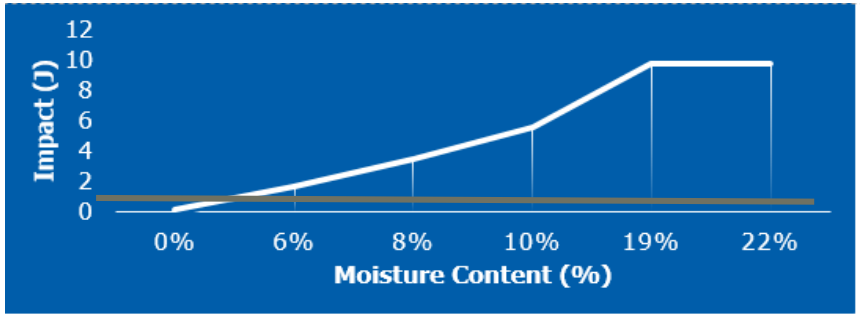
Atmospheric mix drying study and corresponding sensitivity testing to determine safe handling

All moisture levels were ESD sensitive and required a departure

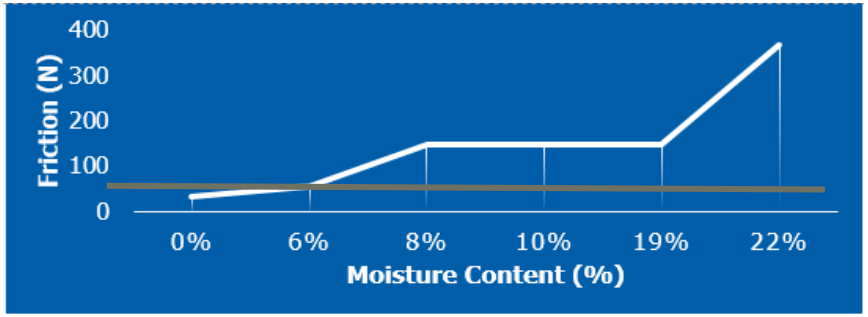
Friction drove the processing time



6% moisture



≥ 0.5J Impact lower limit



≥ 75N Friction lower limit

MIXING AT LCAAP

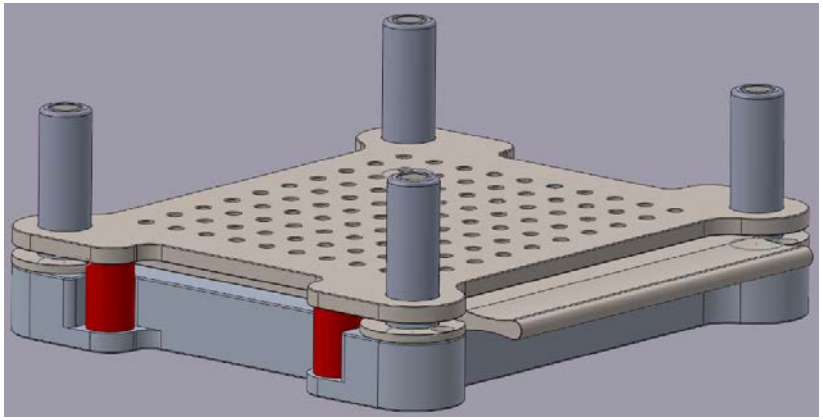
- **Approved for 10-gram mixing operation with DBX-1 primer mix**

- Mixed in a speed mixer at 2,000 rpm
  - All ingredients except fuels added, mixed for two 30-second intervals
  - Fuels added and mixed two additional intervals

PRIMER ASSEMBLY (1)

- Next, we needed to establish a pilot 209 primer assembly process
- Representative of regular LCAAP primer production, amenable to future scale-up
- A few key steps in the process:

1. Cups added to wells in base plate



2. Rub plate added, filled with primer mix

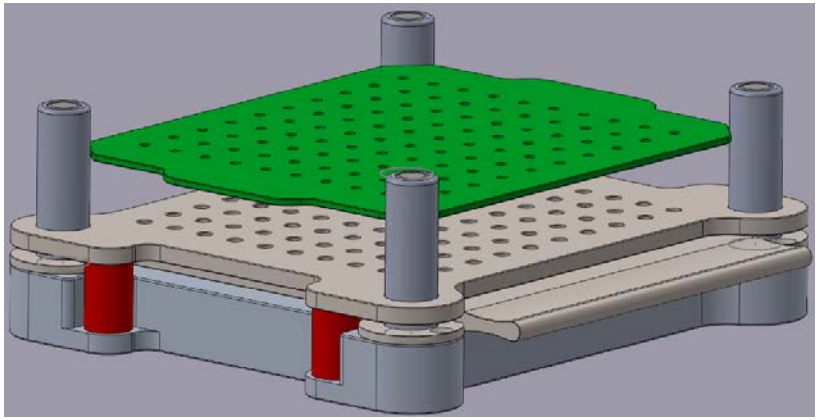
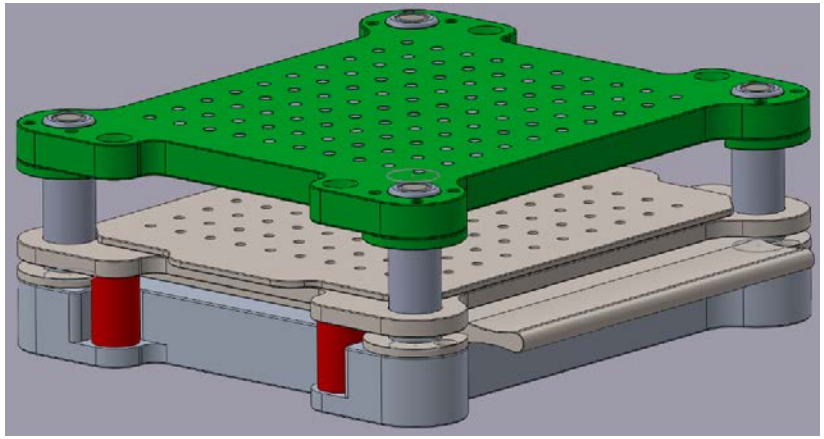


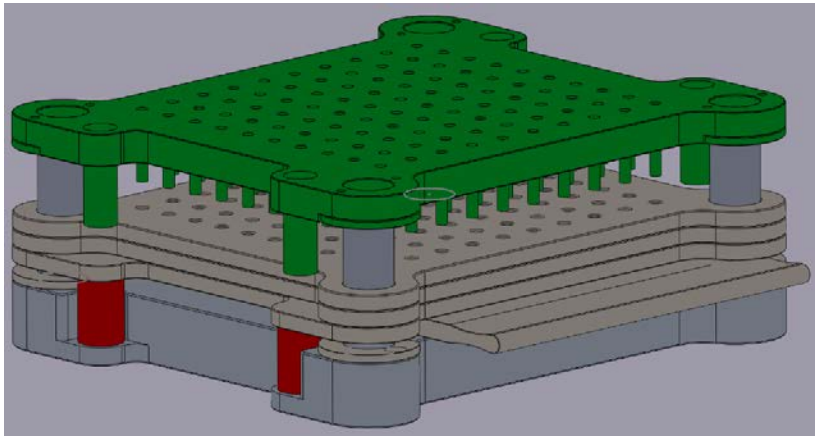
Plate gap controls pellet weight.

PRIMER ASSEMBLY (2)

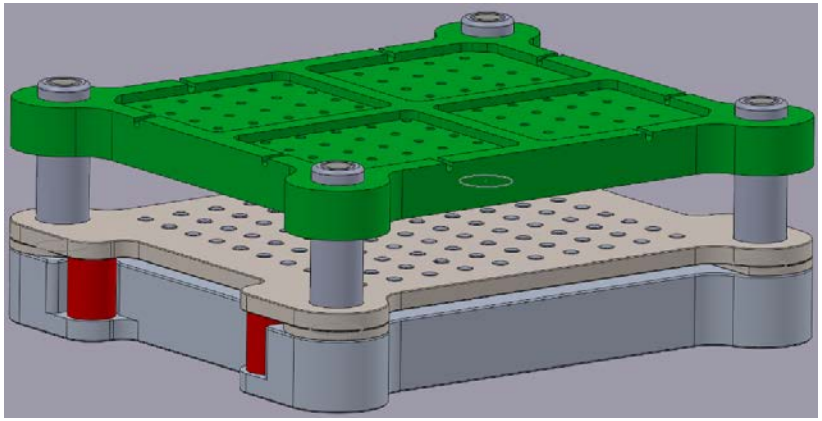
3. Pin pellet plate inserted; pellets shaken into cups



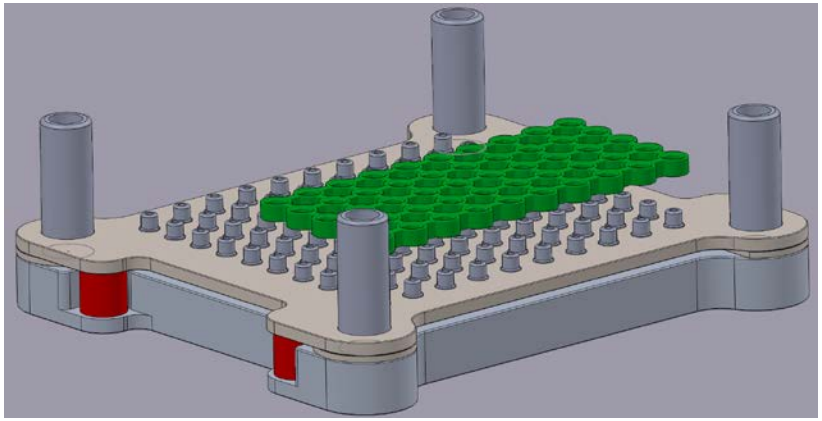
4. Foil punched on top of pellets



5. Battery cups pressed into cups
Plate gap controls anvil-mix distance.



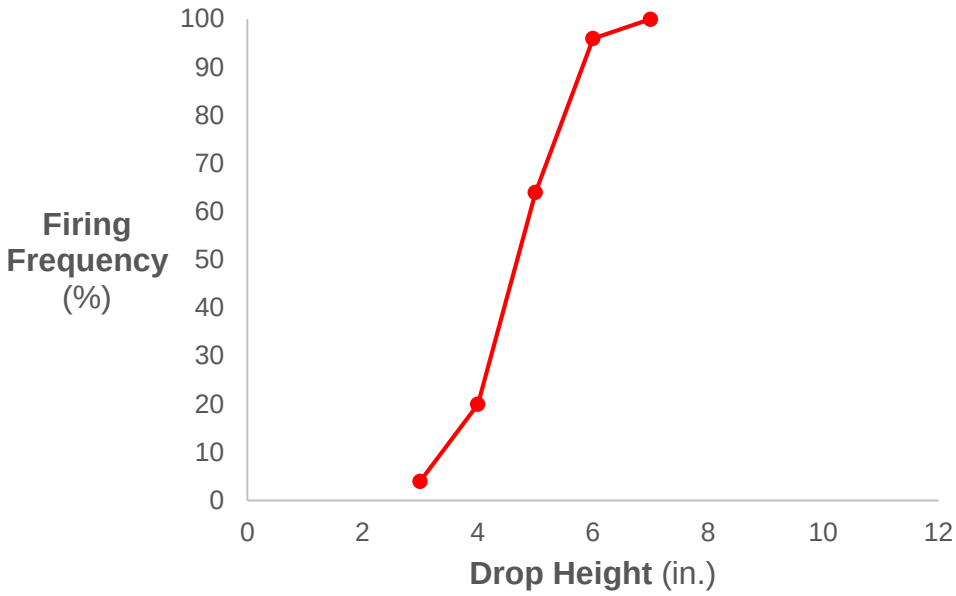
6. Completed primers transferred to packaging sleeve



PRIMER TESTING (1)

- Commercial lot subjected to impact testing to determine firing frequency as a function of impact height

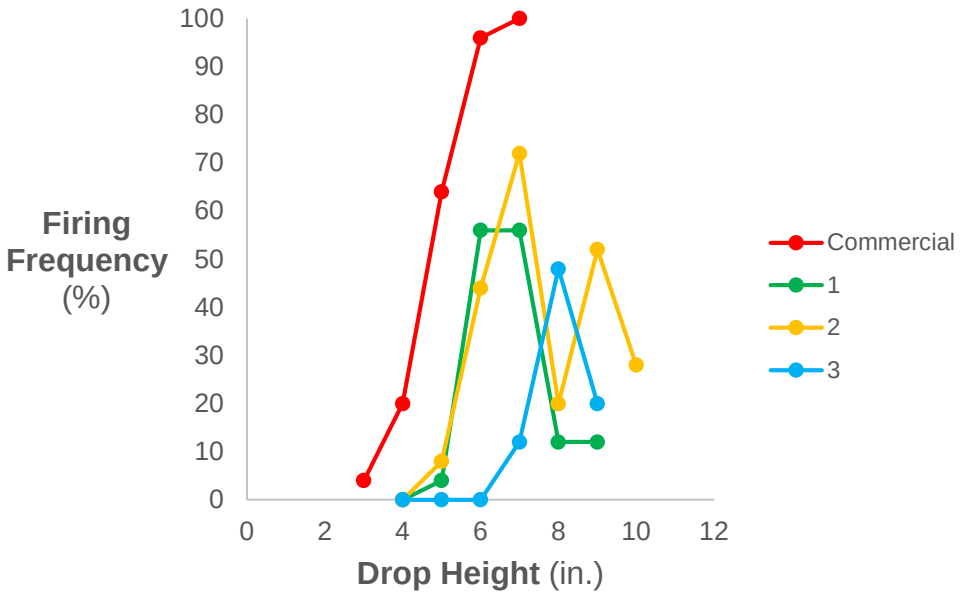
Commercial lot gave virtually linear response to impact



PRIMER TESTING (2)

- Commercial lot tested in parallel with 3 experimental lots that varied assembly parameters
- Initial primer batches gave erratic sensitivity profiles

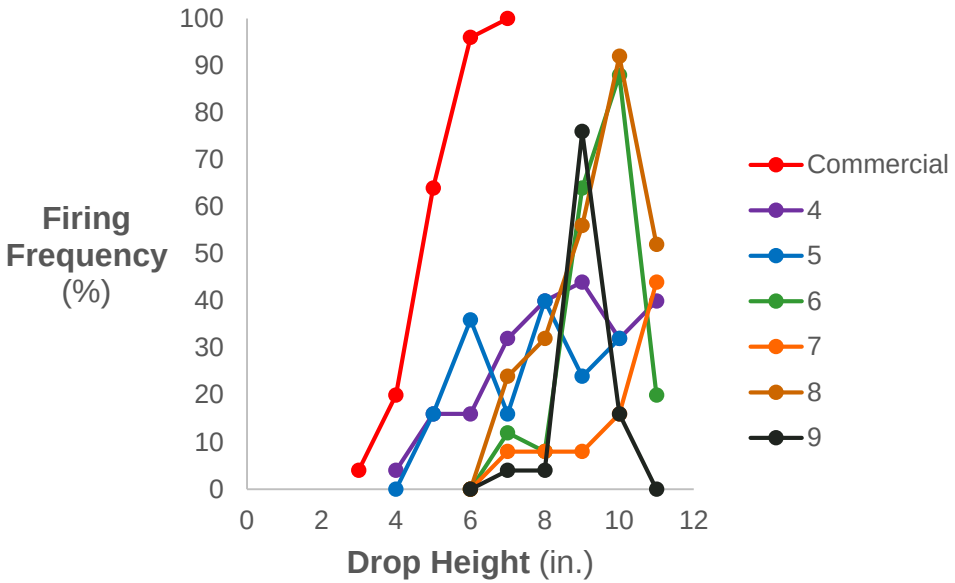
Lot	Pellet Weight
1	0.0694"
2	0.0652"
3	0.0610"



PRIMER TESTING (3)

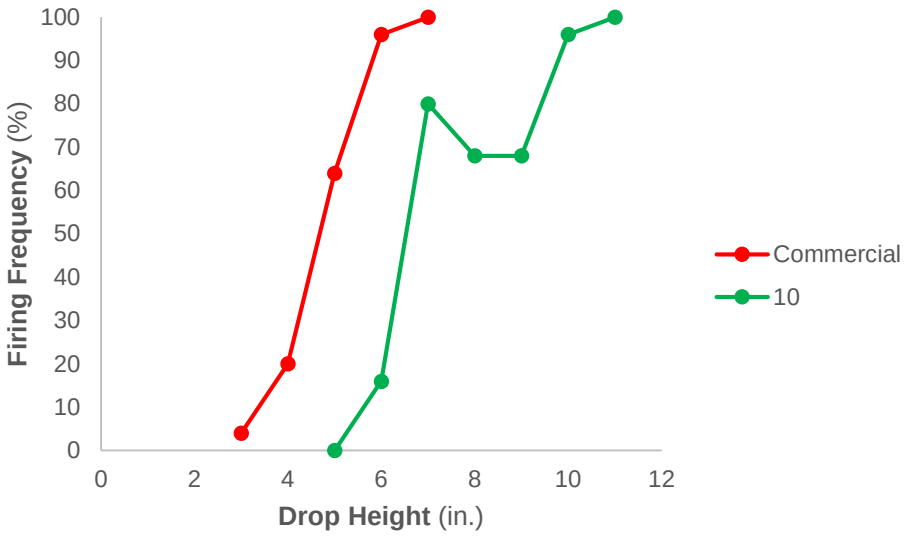
- Made efforts to improve sensitivity profiles by adjusting assembly parameters
  - Pellet plate gap (pellet weight)
  - Battery cup plate gap (sensitivity)
- Tested 6 more lots with alternate manufacturing settings; problems remained

Lot	Pellet Weight	Sensitivity
4	0.0652"	+0.005”
5	0.0610"	+0.005”
6	0.0694"	-0.005”
7	0.0652"	-0.005”
8	0.0610"	-0.005”
9	0.0610"	-0.010”



PRIMER TESTING (4)

- Next hypothesis
  - Erratic behavior due to mix inhomogeneity
  - Pocket formation within mix
- Mix procedure adjusted
  - Screen out coarser KNO_3 particles; remove sub-100 mesh material before mixing, repeat lot 9 assembly parameters
  - Profound improvement
  - Identified all-fire/no-fire energies…
  - …but still no 50/50 point!



Lot	Pellet Weight	Sensitivity
10	0.0610"	-0.010”

SUMMARY

- DBX-1 composition shows promise
- DBX-1 mix has acceptable sensitivity numbers with the exception of ESD
- Challenges working with DBX-1
  - Very sensitive material
    - Water/alcohol does not desensitize it
  - The mix was processed with IPA which reduces available processing time
  - Breaks down in water to more sensitive material
    - Water cannot be used in the process
  - Requires different waste treatment than current materials at LCAAP
    - Waste treatment of DBX-1 mix requires more work

FUTURE WORK

- Work at flare manufacturer will include function testing of lot 10 primers in:
  - Empty HHS rocket barrels
  - HHS rocket barrels with propellant
  - Fully loaded HHSs with rocket motors and payloads
- Completion of above testing will close out HHS program
- Pending results, can transition to other systems, like shotshell