Perchlorate Free Booby Trap Simulators

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May 24, 2007

RDECOM
Technology to the Warfighter Quicker
EALSP

Acknowledgements

Maryalice Miller, Program Director
Environmental Acquisition and Logistics Sustainment Program
Research, Development & Engineering Command

Bill Ruppert, Ordnance Environmental Program Manager
Hughes Associates, Inc.

Dr. Mark Johnson
Dr. Karen Walker
U.S. Army Center for Health Promotion and Preventive Medicine

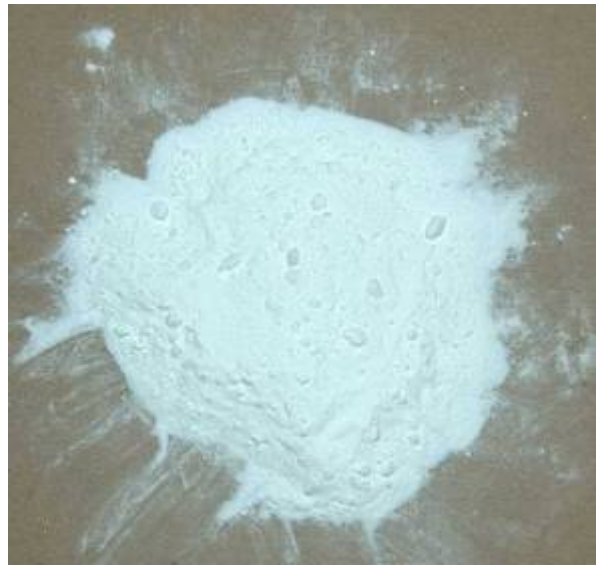
Jim Wejsa, Branch Chief
Picatinny Pyrotechnics R&T Branch

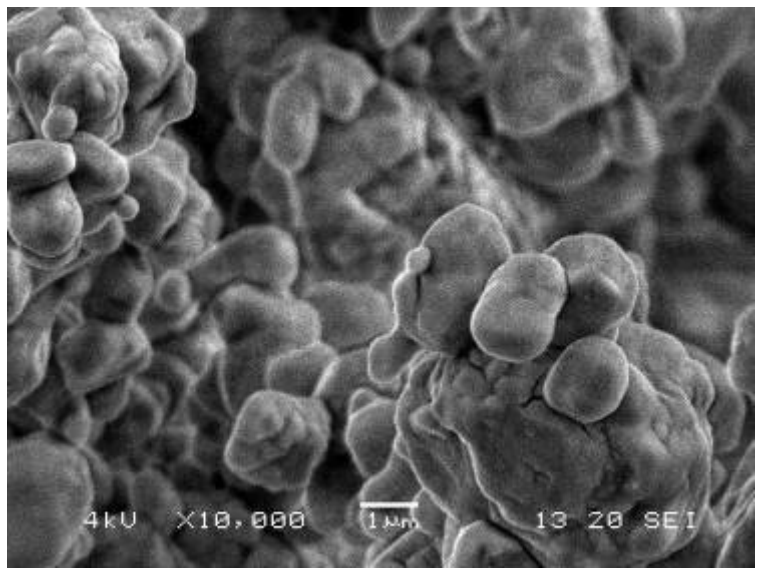
Booby Trap Simulators

- Teaches the installation, detection, and use of booby traps
- Instills caution in troops exposed to traps set by the enemy
- Family of Simulators
  - M117 - Flash Bang
  - M118 - Illumination
  - M119 - Whistle

Potassium Perchlorate ($KClO_4$)

- Widely used in military munitions
  - Very strong, stable oxidizer
  - Low cost
  - Robust (propellant, flash, illumination, whistle)
  - Low water solubility
- Human thyroid impairment
- EPA recommended Drinking Water Equivalent Level – 24.5 PPB





Project Goals

- Environmental Performance Parameters
  - Ingredients
  - Combustion Products
- Elimination of $KClO_4$
- Meet current TDP performance parameters
- Transparency to Users
- Minimize manufacturing differences

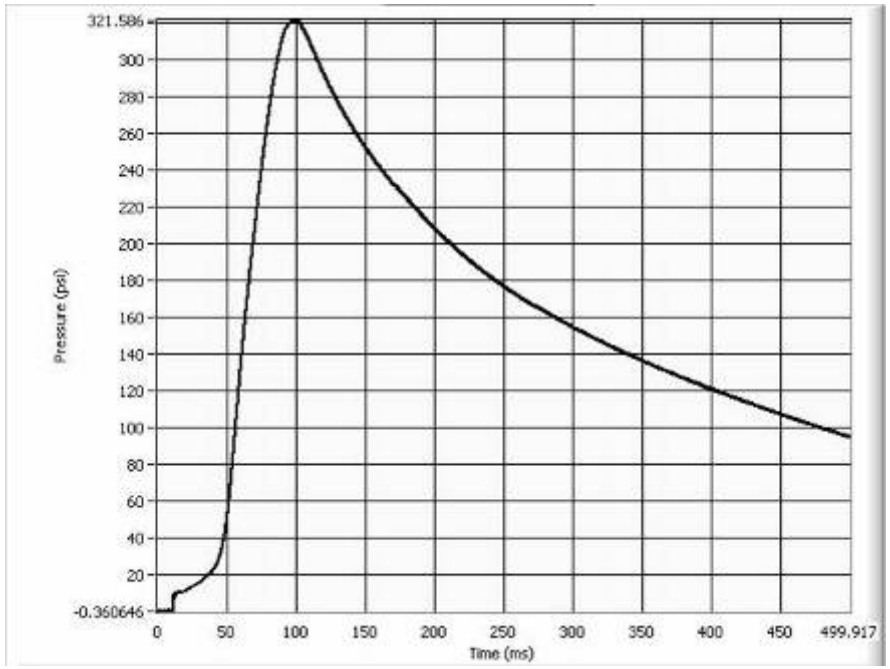
M117 Composition Candidates

Target performance: Flash and 120dB Bang at 25.0±0.5ft

Current Composition	Potassium Perchlorate
	Antimony Sulphide
	Magnesium
M115/116 Formulation #604	Potassium Nitrate Preblend
	Aluminum
	Sulfur
Modified M115/116 Formulation #604	Potassium Nitrate Preblend
	Aluminum
	Sulfur
Gap Flash Powder	Potassium Nitrate Preblend
	Aluminum
	GAP Energetic Binder
M74A1 Flash Powder	Black Powder
	Aluminum

Potassium Nitrate Pre-blended
- Potassium Nitrate
- Boric Acid
- Cab-o-sil

Closed Bomb Testing



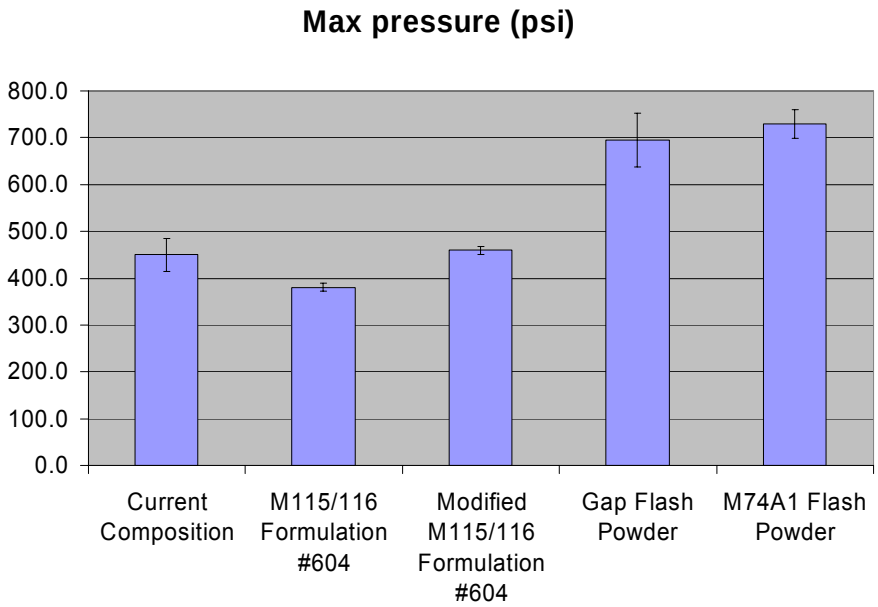
Maximum pressure

Rise time (10% to peak pressure)

Function time (t0 to peak pressure)

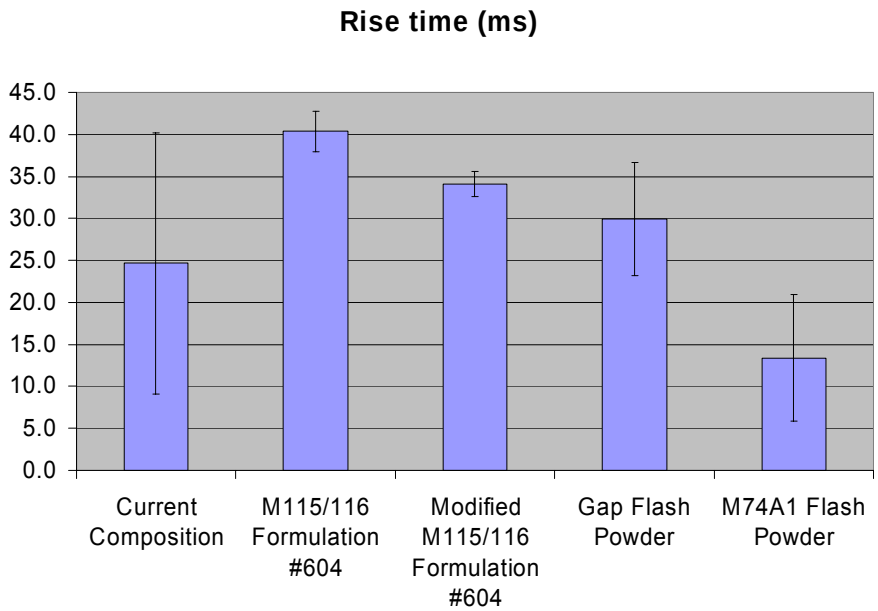
Slope (10% to 90% of peak pressure)

Closed Bomb Data



Initially based load weights by equilibrating max pressure

Rise time shows the impulse of the composition



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M117 Overall Testing Results

Mix	Date	# of Rounds	Quick Match Length	Mixing	Total Weight	Fill Volume	Sound (dB)		# Failing	# of Flash Delays
							Avg	Stdev		
Baseline	4/4/2006	10	Std	In round mixing 10 mins @ 23 rpm Grucci Tumbler	2.50	72%	144.7	5.6	0	7
604	4/4/2006	5	Std		1.50	90%	71.4	65.9	4	5
604	4/4/2006	5	Std		1.20	70%	136.0	4.1	0	2
Modified 604	4/4/2006	5	Std		1.50	90%	135.9	9.4	1	1
Modified 604	4/4/2006	5	Std		1.20	70%	139.0	6.0	0	4
GAP	4/4/2006	5	Std		1.50	90%	105.0	58.7	1	2
GAP	4/4/2006	5	Std		1.00	70%	78.7	71.9	2	1
M74A1	4/4/2006	5	Std		1.55	"= Pressure"	141.9	1.4	0	1
M74A1	4/4/2006	5	Std		1.78	90%	136.8	7.0	0	0
604	4/21/2006	15	Std	In round mixing 30 mins @ 16 rpm on New M115/116 Tumbler	1.20	90%	118.6	8.8	9	12
Modified 604	4/21/2006	15	Std		1.20	77%	116.7	6.9	10	10
Modified 604	4/21/2006	15	Std		1.35	85%	118.6	6.5	9	8
Modified 604	4/21/2006	15	1/2 length		1.20	69%	129.7	9.5	3	4
M74A1	4/21/2006	15			1.20	72%	136.7	3.6	0	3
Baseline	5/10/2006	10	1/2 length	In round	2.50	72%	136.2	5.1	0	0
604	5/10/2006	10	1/2 length	Preblended	1.20	74%	136.4	2.3	0	2
Modified 604	5/10/2006	10	1/2 length	Preblended	1.20	79%	134.4	2.0	0	1
Modified 604	5/10/2006	10	1/2 length	In round mixing 15 mins @ 23 rpm	1.20	69%	121.5	10.8	5	2
GAP	5/10/2006	10	1/2 length		1.20	87%	115.4	11.3	7	0
M74A1	5/10/2006	10	1/2 length		1.20	66%	138.9	1.5	0	0
M74A1	5/10/2006	10	1/2 length		1.20	66%	138.8	2.3	0	1

M117 Videos

M117 Baseline

M117 M74A1

M117 Modified 604

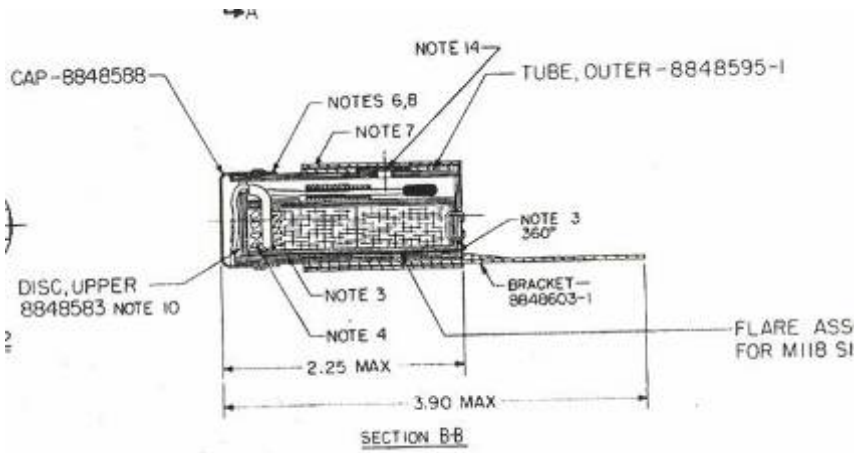
M117 Flash Delay

M117 Conclusions

	M117 Baseline	Modified M115/116 Formulation #604	M74A1 Flash Powder
Sound Level	145dB (4/4/06) 136dB (5/10/06)	135dB	138dB
Load Weight	2.5 g	1.2g	1.2g
Standard Deviation	High	Low	Low
Comments	140dB max sound level	Pre-blended mixes are most reliable	No manufacturing differences

Next Step: limited quantity system demo

M118 Illuminating Simulator



- Target performance
  - 28 second flame duration (minimum)
  - Comparable light output (subjective)

- Current Composition
  - Potassium Perchlorate
  - Red Gum
  - Dextrin

Initial Compositions Candidates

Substitution of $KNO_3/Sr(NO_3)_2$
- Ignition Issues
- Very Fast, low light output

M49 Trip flare – KNO_3/Al/W
- Ignition/Propagation Issues

M90 – KNO_3/C/Gum Arabic
- Very low light

M172 - $NaNO_3$/Mg
- Too Bright/Fast
- Mg out gassing

Iron Oxide – KNO_3/Iron Oxide/Epoxy
- ~40 sec burn time
- Good flame

White Flame – KNO_3/C/S
- Long burn time ~60s
- Inconsistent burn

M118 Testing

- 2 potential formulation systems
  - White Flame (KNO_3/Charcoal/Sulfur)
  - RNX (KNO_3/Fe_2O_3/Epon 828-Epikure 3125)

- 8 iterations of testing
  - Meet burn times
    - Variation of % compositions
  - Increase light output
    - Silicon in white flame
    - Boron in RNX
  - Elimination of slag plug formation during burning

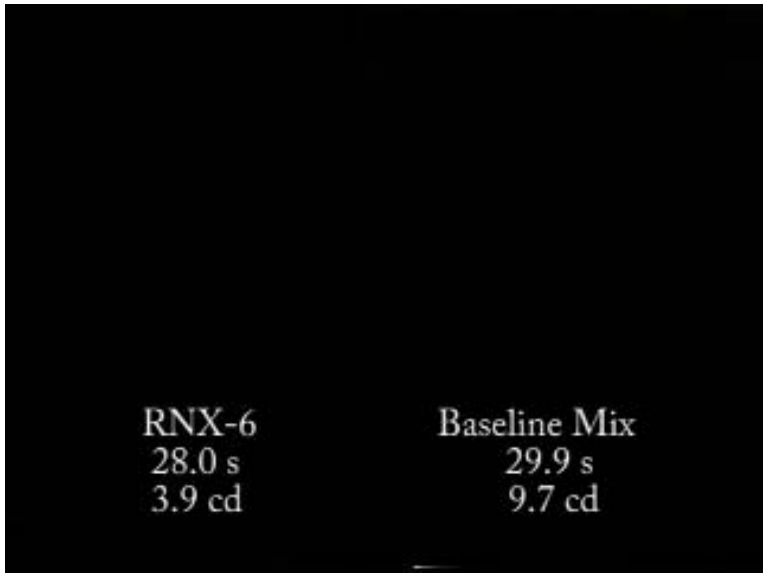
M118 In House Testing Results

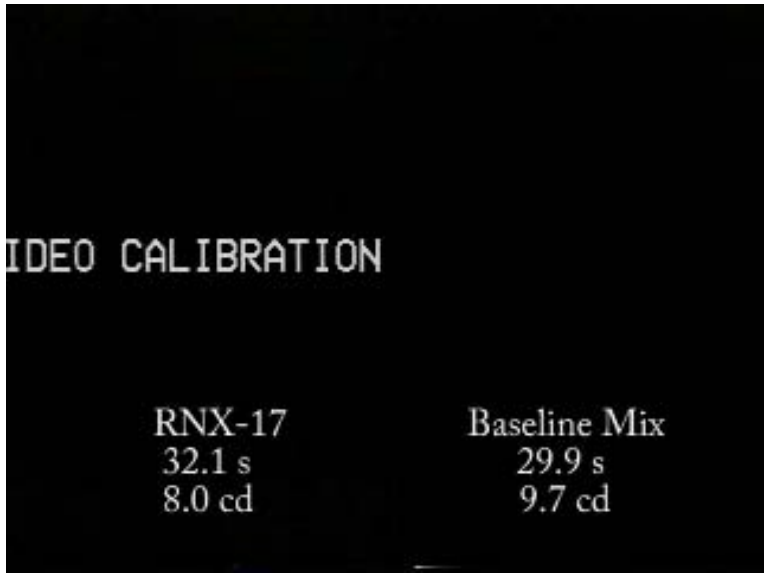
- Down-selected Candidates vs Baseline

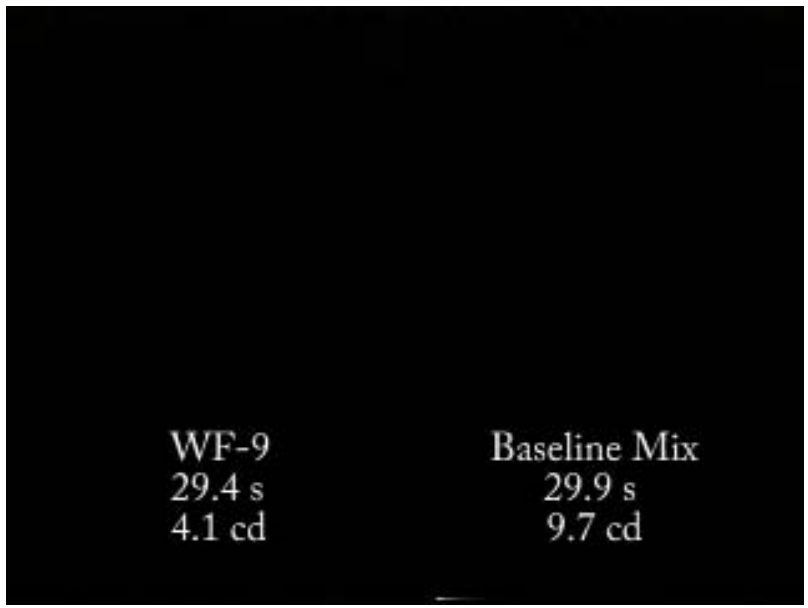
Mix #	Description	Ingredient	Burn Time	Light Output
793	Baseline (4-1.25g inc 500#)	KClO4 Red Gum Dextrin	31.5s	~10Cd*s
830	White Flame 9 (4-1.2g inc 750#)	KNO3 Sulfur Silicon Charcoal VAAR	29.4s	39.20%
826	RNX-6 (4-1.0g inc 750#)	KNO3 Fe2O3 Epon 828 Epikure 3125	28.0s	32.60%
847	RNX-17 (4-1.0g inc 750#)	KNO3 Boron Epon 828 Epikure 3125	32.1s	82.50%

Next Step: limited quantity system demo

M118 Videos on the Down-selected







M119 Previous Lessons Learned

- Target performance
  - 2.5 to 5.0 second whistle
  - Sensitivity equal to or less than current composition (subjective)
    - Friction Test (RDX equivalent)
      - Steel : Detonates
      - Fiber : Unaffected
    - Impact (between RDX and TNT, BP is 16”)
      - 12 inches
- Previous/proven whistle mixes
  - Potassium Nitrate : Potassium Picrate
    - Shock Sensitive
  - Potassium Chlorate : Gallic Acid
    - Friction Sensitive
  - Potassium Perchlorate : Sodium Salicylate (current)

M119 Screening Tests

Quick and Dirty Screen Testing

- Prototype (current cardboard housing)
- Mixes made to stoic. calculations
- Each candidate sample size limited to 2g
- 1 sample per mix
- No binder
- One pressing at 750# load 2s dwell time

Perchlorate Baseline
Major Work Needed
Work Still Needed
Functioning Whistle

	Potassium Benzoate	Sodium Salicylate	Gallic Acid	Terephthalic Acid	Potassium Hydrogen Phthalate
Potassium Perchlorate	Whistle Blew out bottom	whistle	whoosh	whoosh	weak whistle
Sodium Nitrate	fizzle	whoosh	whoosh	fizzle	whoosh
Potassium Nitrate	fizzle	whoosh	whoosh	fizzle	whoosh
Strontium Nitrate	fizzle	fizzle	fizzle	did not burn	fizzle
Cesium Nitrate	fizzle	fizzle	whoosh	fizzle	whoosh
Potassium Chlorate	**Whistle**	Weak whistle / explosion	Whistle	weak whistle	very weak whislte loud whoosh

M119 Video on Initial Test

M119 Continuation Efforts

- Current Potential Candidates
  - Increase whistle quality: parametric testing
    - Modify particle size of fuel
    - Add catalyst/additive to mix
    - Adjust mix to get correct burn time
  - Add binder to mix
  - Establish friction, ESD, and impact sensitivity data
- Future Candidates
  - Continue literature research
  - Evaluate other Benzoic Acid derivative fuels
  - Characterize fuel and oxidizer particle sizes
  - Experiment with low explosive fuels (high oxygen or nitrogen fuels)

Environmental Justification

Challenge – Research and develop perchlorate-free, environmentally benign mix replacements for the M117/M118/M119 pyrotechnic simulators

RDT&E stage – testing

Data available?

- Individual components
  - Chem/Phys Properties – some (relatively benign)
  - Tox Benchmarks – needed for some compounds

Data gaps

- Products of combustion (for some compounds)

Issues – Some issues binders/plasticizers; may be minimal when proportions/quantities are compared.

Environmental Health

***Overall program very successful in reducing environmental risks; with additional improvements made since last IPR:**

Fate & Transport

- Chlorate ion is regulated in groundwater
  - 7 ppm (Maine)
  - 800 ppm (California)

Toxicology

- Exposed groups likely to be soldiers, workers, and human and ecological collaterals.
- Issues exist for:
  - Phthalates – chemical of concern
  - Ecological data absent for some substances

Environmental Health Assessment

M117	Persistence	Transport	Combustion Products	Human Health	Ecologic Health	Data Gaps
Aluminum						
Black Powder						
Cab-O-Sil						
Boric Acid						
GAP Energetic Binder						
Potassium Nitrate						
Sulfur						

	Likely Benign
	Possible Problem
	Probable Problem
	Unknown

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Environmental Health Assessment

M118	Persistence	Transport	Combustion Products	Human Health	Ecologic Health	Data Gaps
Boron						
Charcoal						
Epikure 3125™		Log Kow>3				
Epon 828™						
Potassium Nitrate						
Silicon						
Sulfur						
VAAR						

	Likely Benign
	Possible Problem
	Probable Problem
	Unknown

Environmental Health Assessment

M119	Persistence	Transport	Combustion Products	Human Health	Ecologic Health	Data Gaps
Gallic Acid						
Potassium Benzoate						
Potassium Chlorate						
Potassium Hydrogen Phthalate						
Potassium Nitrate						
Red Gum						
Red Iron Oxide						
Sodium Nitrate						
Sodium Salicylate						
Terephthalic Acid						

	Likely Benign
	Possible Problem
	Probable Problem
	Unknown

Summary

- PM-Close Combat Systems has incorporated funding into their strategic plan
- FY2007-FY2008
  - Completion of Formulation Research and Development
    - M117
      - Complete System Demo on 2 proposed compositions
    - M118
      - Complete System Demo on 3 proposed compositions
    - M119
      - 1 composition shows promise
      - Additional compositions are being formulated
- FY2009-FY2010
  - Complete Energetic Material Qualification
  - Complete Final Hazard Classification
  - Complete Engineering Change Proposal
- FY2011
  - Production begins with New Perchlorate Free Compositions
  - Eliminate the problem before it becomes a source

Questions???

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