



EVALUATION OF NITROCELLULOSE AND GUN PROPELLANTS MADE WITH KRAFT CELLULOSE

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AGENDA



- Introduction
- Propellant selections
- Evaluation of Kraft WC-868
- Evaluation of Kraft AFP-001
- Summary
- Conclusion



BOTTOM LINE UP FRONT (BLUF)

- Kraft NC process can substitute sulfite NC process to avoid single point failure.
- Kraft NC is a viable substitute for sulfite NC for military propellant application.
 - The quality of Kraft NC was verified by testing for compliance with MIL-DTL-224C. A range of selected Kraft NC propellants were tested and met the performance requirements.
 - As compared to legacy configurations, Kraft propellants tend to have higher burn rates/lower charge weights
 - Although drop-in replacement is possible, process optimization may need to be considered

INTRODUCTION: WOOD TO PULP TO NC



Pulping Process

SULFATE (KRAFT)

- Basic digestion
- Universal process for recovery/reuse of pulping chemicals
- Dominant process (Many Mills)
- Use most types of trees

SULFITE

- Acidic digestion
- Tends to degrade cellulose
- Mills diminishing
- Use limited tree species



Pulping

Removes Lignin, hemicellulose



NC Manufacturing



KRAFT CELLULOSE IN GUN PROPELLANTS CONCERNS

- Unknown effects on nitration/nitrocellulose production
- In propellants, differences in fiber morphology could affect:
 - Mechanical properties
 - Safety testing
 - Long term stability
- Unknown effects on propellants/end item performance



PROPELLANT SELECTIONS

Propellant	Ammunition	SIP* test	Rationale
M1MP/M1SP	M67 propelling charge for 105 mm	4 to 5 yr	Short SIP. It assesses the impact of kraft cellulose on stability in a relatively short period.
RPD-596	M1002 cartridge	Recently fielded	New propellant that will replace M14 in M1002 cartridges.
WC-868 ball powder®	Precision Gun Unit (PGU) 20 mm	3 to 5 yr	Tight grain distribution required to meet high-temperature requirements.
AFP-001	Gun Airborne Unit (GAU)-8/A 30 mm	12 to 15 yr	Difficult to make because the exacting ratio of uncoated and coated grains required to meet ballistic requirements.

*SIP: Safe Interval Prediction

WC-868 BALL POWDER®



- WC-868 Ball Powder®: propelling charge currently used in the 20mm PGU family of ammunition
- SMP made one lot of Kraft Ball Powder WC-868 (lot HMS6466-1) to fire in the 20mm PGU-27 A/B Target Practice
- No difficulty or deviations from the regular manufacturing process to make the Kraft WC-868 lot



20mm PGU-27A/B TP

KRAFT WC-868 BALL POWDER®



Function and casualty test

Requirements	Quantity	Baseline (WC-868 lot 2155)	Kraft-based NC propellant (WC-868 lot HMS6466-1)
Pressure at 70 °F ($\bar{X}+3sd \leq 61,500$ psi)	10	53,710 psi	53,788 psi
Velocity at 70 °F ($\bar{X}= 3410\pm50$ fps) ($SD \leq 10$ fps)	10	3,384 fps 9 fps	3,411 fps 10 fps
Action Time at 70 °F ($X \leq 4.0$ msec) ($\bar{X}+4sd \leq 4.0$ msec)	10	2.62 msec 2.82 msec	2.56 msec 2.64 msec
Action time at 145 °F (X - no requirement) ($\bar{X}+4sd$ - no requirement)	10	2.48 msec 2.52 msec	2.43 msec 2.51 msec
Action time at -65 °F ($X \leq 4.0$ msec) ($\bar{X}+4sd \leq 4.0$ msec)	10	2.82 msec 3.06 msec	2.69 msec 2.85 msec
Function & casualty at 70, 145, & -65 °F	100, 100, 100	All functioned with no casualty	All functioned with no casualty

Kraft WC-868 met the pressure, velocity, action time, and the Function & Casualty requirements of AS-6119A

AFP-001 PROPELLANT



- AFP-001

- Air Force fielded single base propellant for 30-mm Precision Gun Unit (PGU)-15A/B Target Practice (TP) ammunition
- Target muzzle velocity is achieved by blending grains coated with methyl centralite (MC) and base grain





KRAFT AFP001 GENERATED EXTREMELY HIGH PRESSURES AT AMBIENT

Blend	CW (grams)	Velocity (ft/sec)	Pressure (PSI)
Sulfite	145	3022	31510
Kraft	140	3428	63986

Kraft 5.4% MC component burn extremely fast.

Sample	% MC	% Retention
AFP-001 Kraft 5.4% coated	3.19	59
AFP-001 Sulfite 5.4% coated	4.8	89

Had higher MV and P than sulfite propellant

- Kraft fibers are coarser than sulfite fibers, allowing for greater inter-fiber space providing less bonding area that results in a more porous surface.
- Kraft AFP001 propellant retained 33% less MC than the baseline as result burned too fast.



COATING DESIGN OF EXPERIMENT

Run	Coating Time (min)	Solvent/Propellant Ratio	Alcohol/Water Ratio
1	60	0.4	1.50
2	60	0.8	1.50
3	60	0.4	0.67
4	60	0.8	0.67
5	120	0.4	1.50
6	120	0.8	1.50
7	120	0.4	0.67
8	120	0.8	0.67
9	60	0.4	1.0

A three factor, two level full factorial, for coating design was conducted to identify the levels that will minimize Relative Quickness (RQ).

OPTIMIZED COATING PARAMETERS DID NOT SLOW PROPELLANT BURN



Table: RQ and %MC retained for samples coated at 5.4% methyl centralite

	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Baseline
RQ	92	102	91	98	84	99	90	93	89	79
%MC	3.13	1.43	2.99	2.49	3.73	1.70	3.14	3.08	3.38	4.66

Only coating run #5 produced a RQ similar to the baseline (RQ 78.96).
Run #5 retained 25% less MC than the baseline.

PROCESSING STUDY FOR REDUCING POROSITY



Factors	AFP001 Baseline	Run 1	Run 2	Run 3	Run 4	Run 5
Mix time	1	2	2	2	2	2
Web	1	2	2	2	3	3
Die length	1	1	1	2	2	2
Solvent Recovery hold time	1	1	2	2	2	2
Solvent Recovery ramp time	1	1	2	2	2	2
Solvent Recovery cycle temp	1	1	1	1	1	2

- Increasing mixing time to increase more work to the dough prior to extrusion and further improve the homogeneity of the dough
- Evaluate web size effect on velocity
- Longer extrusion die length to increase consolidation pressure
- Solvent recovery in a less forceful way to prevent outer layer from hardening too fast



INITIAL SCREENING EFFORT

Parameter	RAY BG-1	RAY BG-2	RAY BG-3	Baseline 171127-02	G00001 MC	B00002 MC	P00003 MC	Baseline 171127-01
% RS	0.76	0.69	0.85	0.70	0.48	0.42	0.63	0.58
RQ	103.4	106.8	101.5	108	80.4	85.9	75.9	81.9
%MC	--	--	--	--	3.77	3.70	4.15	4.44
% MC Retention	--	--	--	--	69.8	68.5	76.9	82.2

- RQ for base grains RAY BG-1 to BG-3 were similar to slightly slower than the baseline and were selected for deterrent coating
- For the deterrent coated propellant, the amount of methyl centralite (MC) retained on the grains was improved compared to prior effort
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- Batch P00003 MC was processed with all manufacturing process treatments:
 - RQ lower than the other two batches processed with fewer process treatments and the baseline.
 - Retained about 10% more MC than G00001MC and B00002MC
 - Retained about 7% less MC than the sulfite baseline MC-Comp 171127-01 propellant.

BALLISTIC PERFORMANCE OF 5.4% MC COMPONENT



Sample	CW (g)	Velocity (ft/sec)	Pressure (psi)
G00001 MC	145	3108	38084
B00002 MC	145	3216	43107
P00003 MC	145	2988	33137

- The ballistic performance of the MC coated samples was assessed by firing three rounds each at ambient at nominal charge weight of 145 grams.
- Velocity and pressure results are within the workable range.
- Reference: sulfite 5.4% MC samples historically generate velocity about 3022 ft/sec, and pressure 31,500 PSI.

FIRST ITERATION BLENDS SCREENING TESTS



Lot	Blend Ratio MC-BG	No. Rounds	Test Temp. F	Velocity (ft/sec)	Pressure (sd) PSI	Action time (sd) msec
G00001MC/BG	84/16	4	70F	3317 (7.4)	50189 (528)	4.15 (0.049)
G00001MC/BG	84/16	4	-65F	3145 (13.3)	40474 (756)	4.76 (0.072)
G00001MC/BG	84/16	4	160 F	3450 (6.2)	59372 (637)	3.83 (0.040)
P00003MC/BG	78/22	3	70F	3290 (10.3)	49630 (464)	4.34 (0.087)
P00003MC/BG	78/22	3	160F	3409 (2.9)	56570 (219)	4.09 (0.036)
B0002MC/BG	93/7	4	70F	3336 (4.2)	51202 (428)	4.29 (0.079)
B0002MC/BG	93/7	3	-65F	3206 (23.5)	43425 1576)	4.82 (0.094)
B0002MC/BG	93/7	3	160 F	3436 (4.9)	56850 (630)	4.10 (0.081)

Target velocity
3350±25 ft/sec at
70F Charge weight
145 grams.

- To make AFP001 lots that meet ballistic requirements, amounts of 5.4% MC coated propellant are blended with amounts of their respective base grains.
- Three blends were made and tested. Blend G84-16 means, 84% coated propellant and 16% base grain.
- Green sample G00001MC and pink sample P00003MC needed adjustment to meet the target velocity.
- Blue sample met it.

BALLISTIC RESULTS FOR OPTIMIZED BLENDS



Sample	MC Coat	%BG	Rounds	CW	Vel	Vsd	P	Psd	P +3sd	AT	ATsd
BSO18C-S73378	G83/17	17	3	145	3292.9	11.2	47836	577	49567	4.177	0.049
BSO18C-S73378	G83/17	17	3	147	3333.6	13.4	49511	1073	52730	4.056	0.073
									0		
BSO18C-S73379	B93/7	7	3	145	3327.2	6.7	49010	393	50189	4.106	0.035
BSO18C-S73379	B93/7	7	3	147	3365.3	2.2	52635	78	52869	4.022	0.045
BSO18C-S73380	P75/25	25	3	145	3314.6	4.9	49962	768	52266	4.175	0.03
BSO18C-S73380	P75/25	25	3	147	3343.6	4.4	51213	374	52335	4.205	0.048

Sulfite calibration lot at 147 grams: Velocity 3334 ft/sec and pressure of 51,707 PSI

- Blends with corrected ratios loaded at 145 and 147 grams respectively
- All three samples met the requirement of the specifications for 30mm GAU-8 round at the desired charge weight of 147 grams.
- These values compare very well with those results of the sulfite calibration lot

Key 30mm GAU-8 Ballistic Limits

Velocity at 70 F = 3350 +/- 25 ft/sec

P+3sd < 60,400 psi at 70F and -65F

P+3sd < 65,600 psi at 160F

Action Time < 5.1 msec at 70F at 160F

Action Time < 5.5 msec at -65F



LAT GUN TEST RESULTS

Sample	Blend Ratio (MC/B G)	CW (grams)	Temp (F)	Velocity (ft/sec)	Vsd	Pressure (Psi)	Psd	P+3sd	Action Time (msec)	ATsd	delta V amb to hot	delta P amb to hot
BSO18C-S73378	83/17	147.9	-65	3208	7.9	44148	511	45681	4.7	0.076		
BSO18C-S73378	83/17	147.9	70	3343	6.4	51000	543	52629	4.18	0.058		
BSO18C-S73378	83/17	147.9	160	3453	7.1	56824	721	58987	3.95	0.046	110	5824
BSO18C-S73379	93/7	146.4	-65	3205	11.5	42918	941	45741	4.71	0.139		
BSO18C-S73379	93/7	146.4	70	3338	7.6	51502	653	53461	4.16	0.049		
BSO18C-S73379	93/7	146.4	160	3439	5.7	56419	577	58150	3.97	0.035	101	4917
BSO20A-S73502	75/25	147.5	-65	3296	4.1	49654	609	51481	4.38	0.042		
BSO20A-S73502	75/25	147.5	70	3360	16.4	54423	1559	59100	3.97	0.108		
BSO20A-S73502	75/25	147.5	160	3442	7.5	58407	653	60366	3.85	0.04	82	3984

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Velocity at 70 F = 3350 +/- 25 ft/sec

P+3sd < 60,400 psi at 70F and -65F

P+3sd < 65,600 psi at 160F

Action Time < 5.1 msec at 70F at 160F

Action Time < 5.5 msec at -65F

- All three lots met the requirements of the specifications.
- Kraft nitrocellulose is a viable substitute for sulfite NC for AFP-001



SUMMARY

- The selected propellants for evaluation included single base propellant (M1, AFP001), double base propellant (RPD596), and ball powder (WC-868). AFP001 was selected also because it is difficult to make.
- The performance of all four Kraft M1, RPD596, WC-868 and AFP001 propellants met the spec requirements

Note: Kraft NC quality for compliance with MIL-DTL-224C and performance of Kraft M1 and RPD596 were presented at the last NC symposium



CONCLUSION

- Kraft NC process can substitute sulfite NC process to avoid single point failure.
- Kraft NC is a viable substitute for sulfite NC for military propellant application.
 - The quality of Kraft NC was verified by testing for compliance with MIL-DTL-224C. A range of selected Kraft NC propellants were tested and met the performance requirements.
 - As compared to legacy configurations, Kraft propellants tend to have higher burn rates/lower charge weights
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THANK YOU.

