LESS SENSITIVE AND “GREEN” PROPELLANT

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Less Sensitive Replacement for SSE Propellant

Typical single base propellants such as the M1 and M14 families that contain 4% to 10% DNT are not IM compliant and are especially sensitive to shock.

These propellants usually fail the following IM tests:

- Bullet Impact (BI)
- Fragment Impact (FI)
- Shaped Charge Jet Impact (SCJI)
- Sympathetic detonation (SD)

“Green” Raw Materials

There is a world-wide drive towards “Green” propellants and explosives and the aim is to achieve the following:

- Replace suspected carcinogenic substances such as DNT (di-nitrotoluene), DBP (di-butyl phthalate) and other phthalates and DPA (di-phenyl amine)
- Lead and most other heavy metals have already been replaced
- Reduce or eliminate the large quantities of solvents released into the atmosphere during propellant processing

“Green” and Less Sensitive Candidates

Three different propellant families proposed as IM candidates:

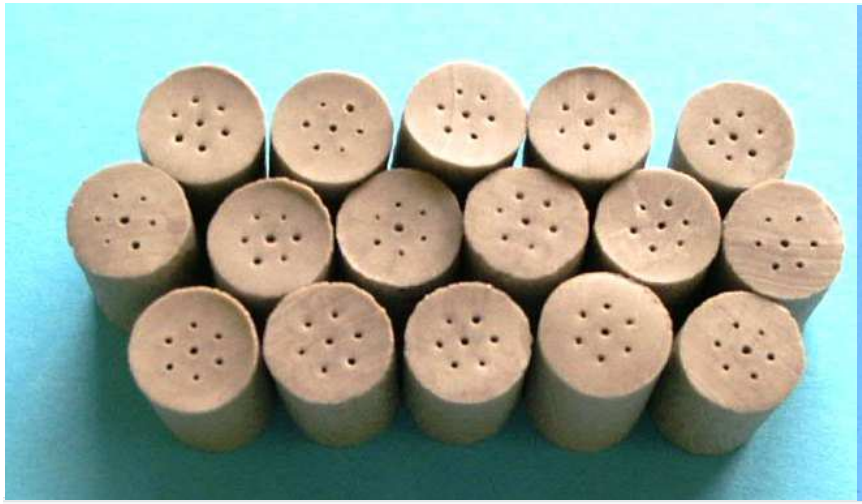
- A single base formulation with additional DBP and increased NC to maintain energy level
- A formulation with 20% of energetic plasticiser TEGDN and decreased NC to maintain energy level
- A triple base formulation with DEGDN instead of NG and 20% NQ plus DEP

SSE/Mod-1

- A single base formulation with additional DBP and increased NC to maintain energy level
- 100 kg processed according to SSE process
- Passed Bergman & Junk and Methyl Violet stability tests
- Complies with SSE energy specification
- Relative vivacity and pressure complies with SSE specification

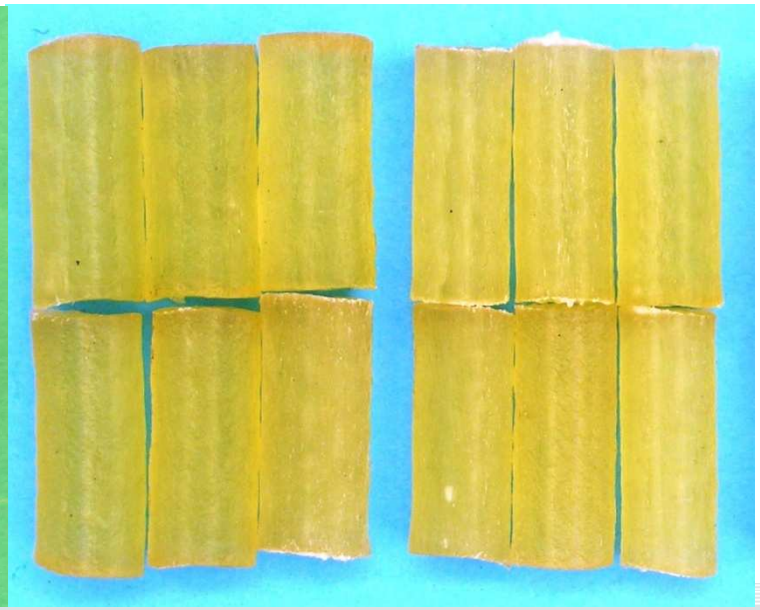
DEGDN Formulation

- A triple base formulation with DEGDN instead of NG and 20% NQ plus DEP
- 4 Iterations processed and extruded with various dies
- Passed the Methyl Violet stability test
- Energy slightly higher than SSE specification



TEGDN Formulation

- A formulation with 20% of energetic plasticiser TEGDN and decreased NC to maintain energy level. DBP was initially included.
- 4 Iterations processed according to solvent process and extruded with various dies
- All iterations passed the Methyl Violet stability test
- The energy was initially slightly lower than SSE specification



Propellant Grains: Solvent Process versus Solvent-Free

Thermochemical Properties of Less Sensitive Candidates

PROPERTY	STD SSE	SSE/MOD-1	DEGDN	TEGDN
Specific energy (J/g)	927.2	925.8	932.6	929.4
Flame temperature (K)	2591.9	2601.6	2413.1	2536.1
Density - TMD (g/cm^3)	1.604	1.589	1.548	1.556

Closed Vessel Data of Propellant Formulations

No	-20°C		+21°C		+60°C	
	RV (%)	RP (%)	RV (%)	RP (%)	RV (%)	RP (%)
TEGDN-5	88.8	100.1	**95.3**	100.9	102.5	103.2
DEGDN-8	89.0	102.5	**96.8**	103.7	105.7	107.1
SSE/Mod-1	91.6	98.0	98.0	98.6	103.1	100.8
SSE Ref	95.9	99.1	100.0	100.0	103.3	102.1

Gun Firing Data of Propellant Formulations

Propellant	Temp	Charge Mass (kg)	Vo (m/s)	Pressure (MPa)
SSE lot 260 (reference)	21°C	2.40	890.4	283.1
Mod-1	21°C	2.40	857.6	236.0
DEGDN-8	21°C	2.40	898.3	286.0
TEGDN-5	21°C	2.40	920.3	332.6

IM Testing and Evaluation

IM tests performed on the candidate formulations were :

- Slow cook-off test (STANAG 4382)
- Bullet impact test (STANAG 4241)
- Shape charge jet test (STANAG 4526)
- Fast cook-off test (STANAG 4240)

Test Configuration – EMTAP Tubes with Propellant

Description of Reaction Categories (STANAG 4491)

Category	Reaction Description	Observation
0	No reaction	Internal inspection
0/1	Burning/Decomposition	No disruption of test vehicle
1	Pressure burst due to burning/decomposition	Test vehicle ruptured but one fragment obtained
2	Deflagration	2 to 9 test vehicle body fragments
3	Explosion	10 to 100 test vehicle body fragments
4	Detonation	> 100 test vehicle body fragments showing evidence of detonation

Test Configuration – Slow Cook-off

Slow Cook-off

SSE

DEGDN

Test Configuration – Fast Cookoff

Fast Cook-off

SSE

DEGDN

TEGDN

Bullet Impact

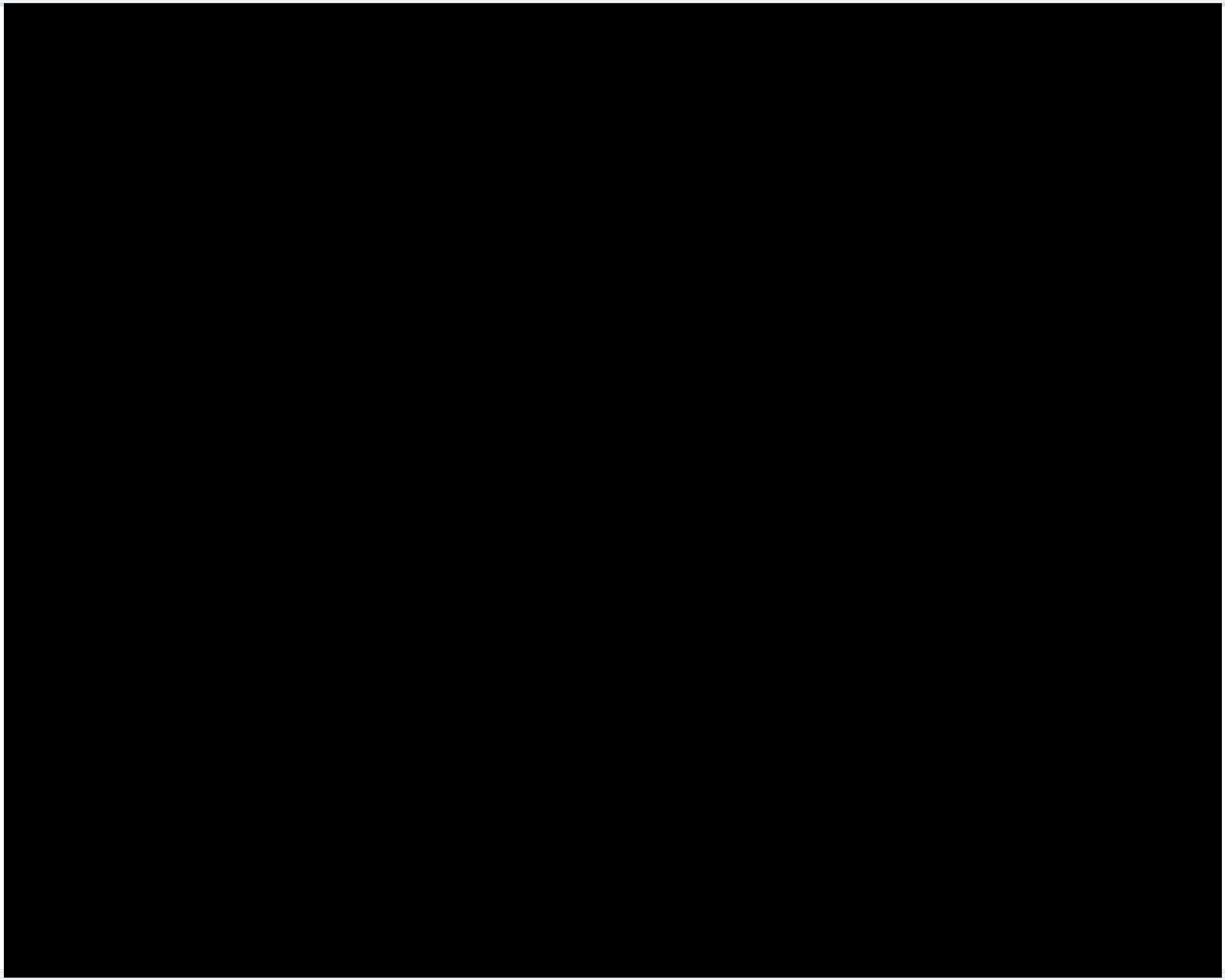
SSE

SSE/Mod-1

Bullet Impact

DEGDN

TEGDN



Shape Charged Jet – SSE

Shape Charged Jet - SSE/Mod-1

Shape Charged Jet – DEGDN

Shape Charged Jet - TEGDN

Summary of IM Test Results

Propellant	Slow Cook-off		Fast Cook-off	Shape Charge Jet	Bullet Impact
	Temp.	Reaction			
SSE	147°C	2	2	2 / 3	2
SSE/Mod-1	153°C	2	2	2 / 3	2
DEGDN	150°C	2	2	0 / 1	0 / 1
TEGDN	146°C	2	2	0 / 1	0

Conclusions

- All 3 candidates were successfully processed and evaluated
- Friction and impact sensitivities have been performed
- Chemical stability testing has been performed according to STANAG 4582 and AOP-48, shelf-life > 10 years
- DEGDN and TEGDN formulations passed all IM tests and will be further evaluated as SSE replacements
- Further web and processing iterations have been performed
- Closed vessel ballistics of DEGDN and TEGDN matched SSE – ready for weapon firings

Less Sensitive Replacement for SSE - Future Work

- Fire and evaluate DEGDN-8 and TEGDN-5 configurations in 76mm weapon
- Improve and optimise solvent processing of TEGDN formulation
- Make a TEGDN/NC paste and evaluate solvent-less processing of TEGDN formulations
- Repeat IM & sensitivity testing on modified formulations
- Perform IM testing of final SSE replacement propellant in fully assembled 76mm Naval round

Acknowledgements

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  and

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Vielen Dank!