



FOLLOW-UP TO LESS SENSITIVE AND “GREEN” PROPELLANT

Charles Wiehahn

IM & EM Technology Symposium

Las Vegas, May 2012





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



Initial “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 the energetic plasticiser TEGDN and NC
– solvent processed
- A formulation with DEGDN instead of NG and with NQ making it a modified triple base – solvent-less processed



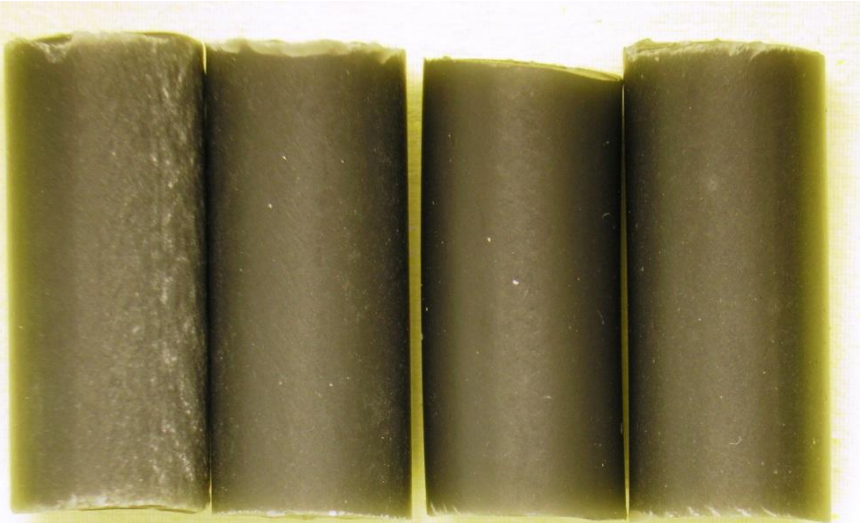
Solvent-less TEGDN Formulations

Change processing from solvent based to solvent-less:

- Improved processing and made formulation “greener”
- Made and evaluated TEGDN/NC pastes with various types of NC
- Evaluated different ratios of TEGDN to NC
- TEGDN/NC ratio of 40/60 rolled & extruded best and gave the best mechanical properties
- Ballistic evaluation was required and IM properties had to be confirmed



Solvent-less TEGDN Formulations



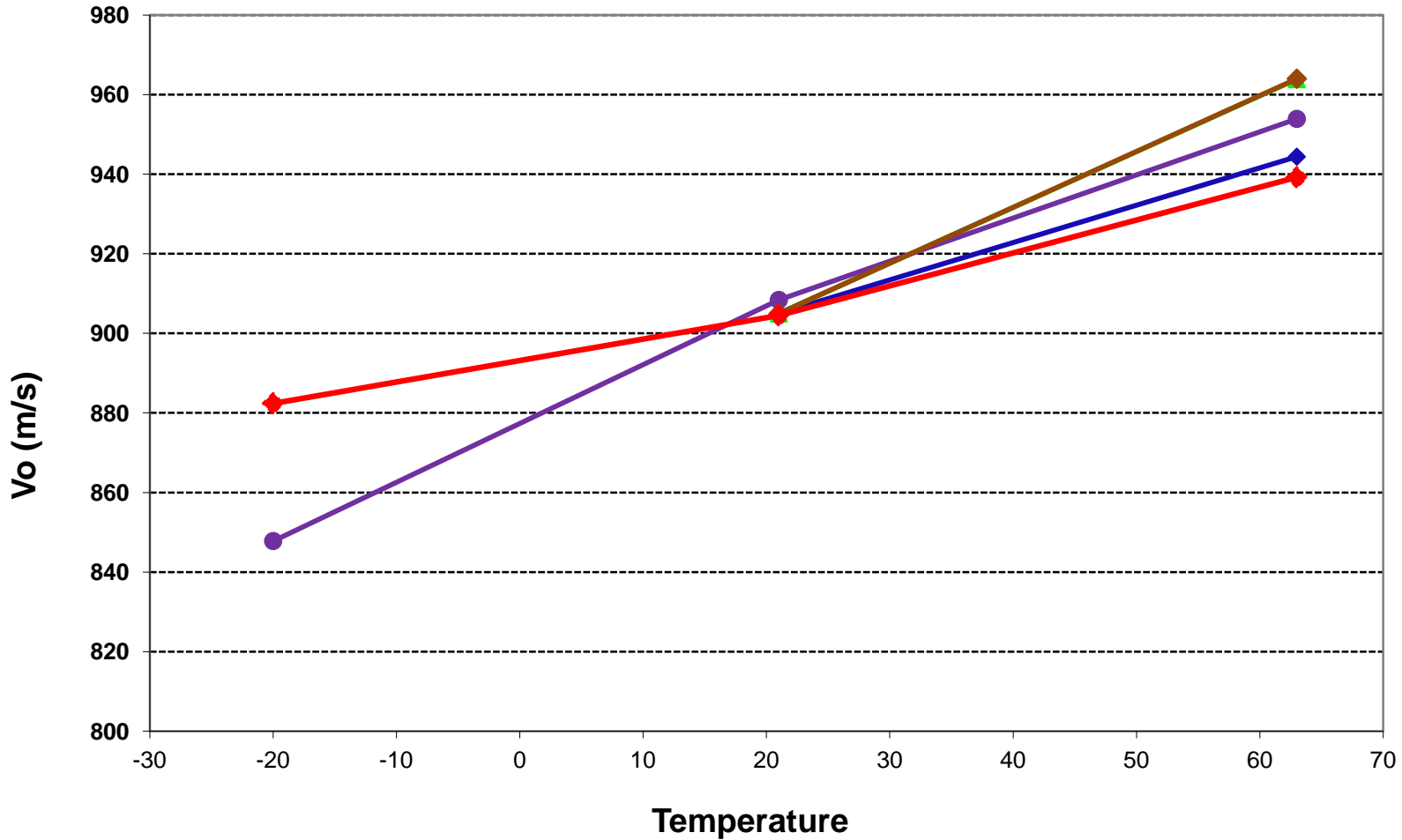


Closed Vessel Data of Propellant Formulations

Propellant	Relative Vivacity (%)	Relative Pressure (%)
TEGDN-P7	96.0	104.3
TEGDN-P9	85.2	103.0
TEGDN-P15	95.4	104.5
DEGDN-10	98.8	102.2
SSE Reference	100	100

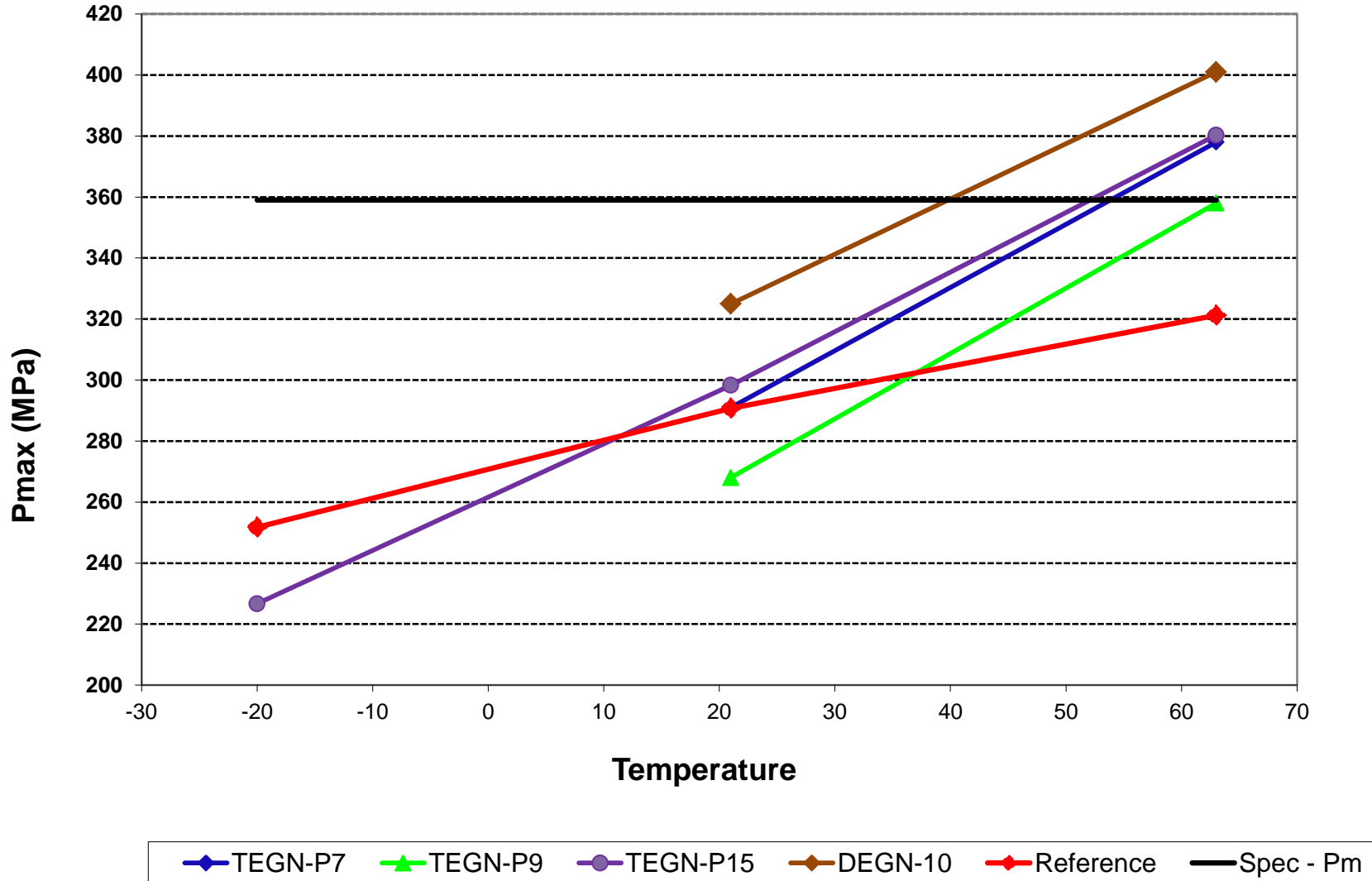


76mm Gun Firing: Vo versus Temperature - TEDGN & DEGN Formulations





76mm Gun Firing: Pmax versus Temperature - TEGDN & DEGN Formulations





Alternative Propellant Formulations

- Traditional Triple Base Formulation
- Single base Propellant Formulation with Inert Plasticiser
- Single base Propellant Formulation with Inert Plasticiser and RDX



Traditional Triple Base Formulation





Single Base Propellant Formulation with Inert Plasticiser



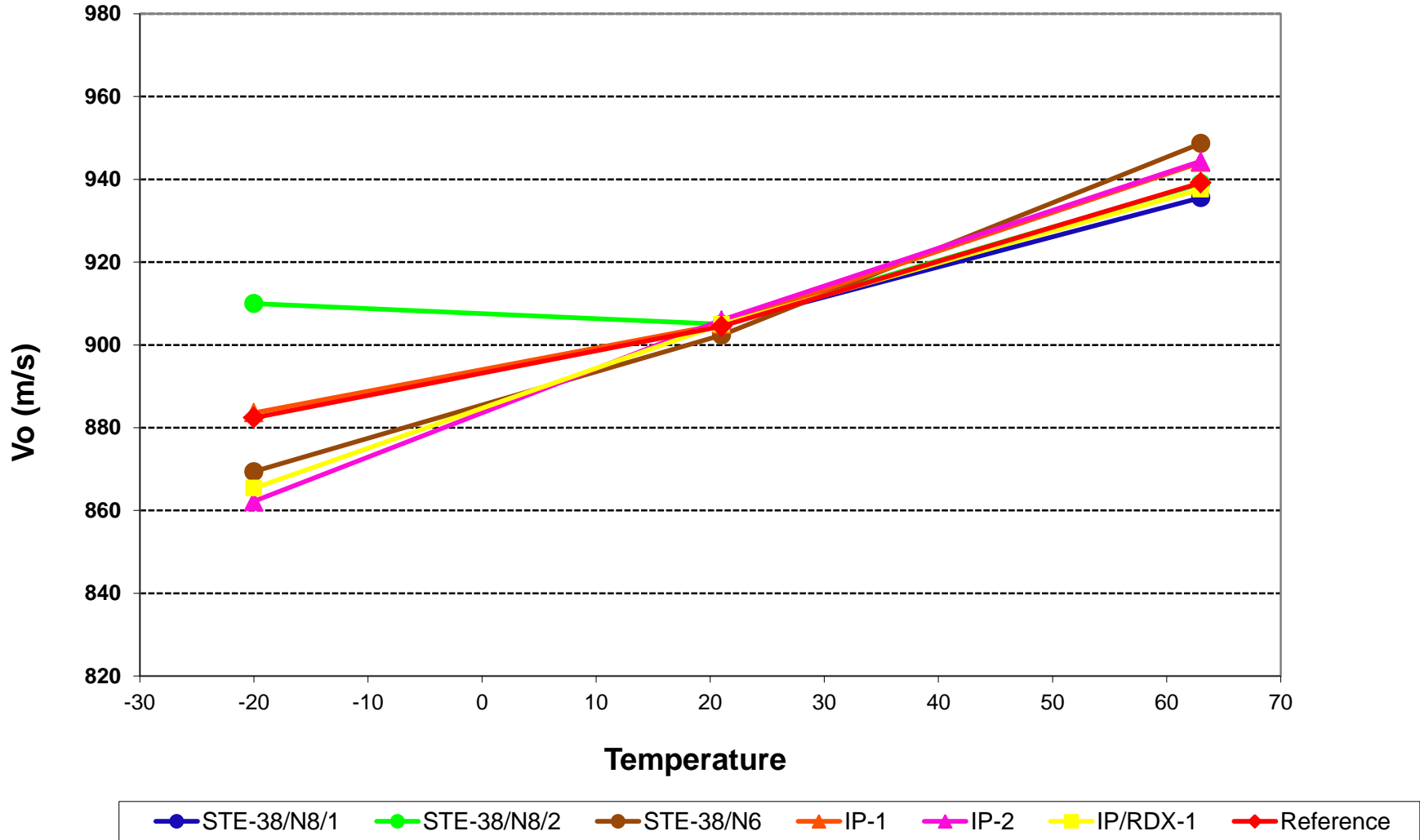


Closed Vessel Data of Alternative Propellant Formulations

Propellant	Relative Vivacity (%)	Relative Pressure (%)
STE-38/N8/1	106.4	111.7
STE-38/N8/2	99.5	111.8
STE-38/N6	96.2	111.9
IP-1	94.9	99.6
IP-2	94.1	99.1
IP/RDX-1	105.7	102.7
SSE Reference	100	100

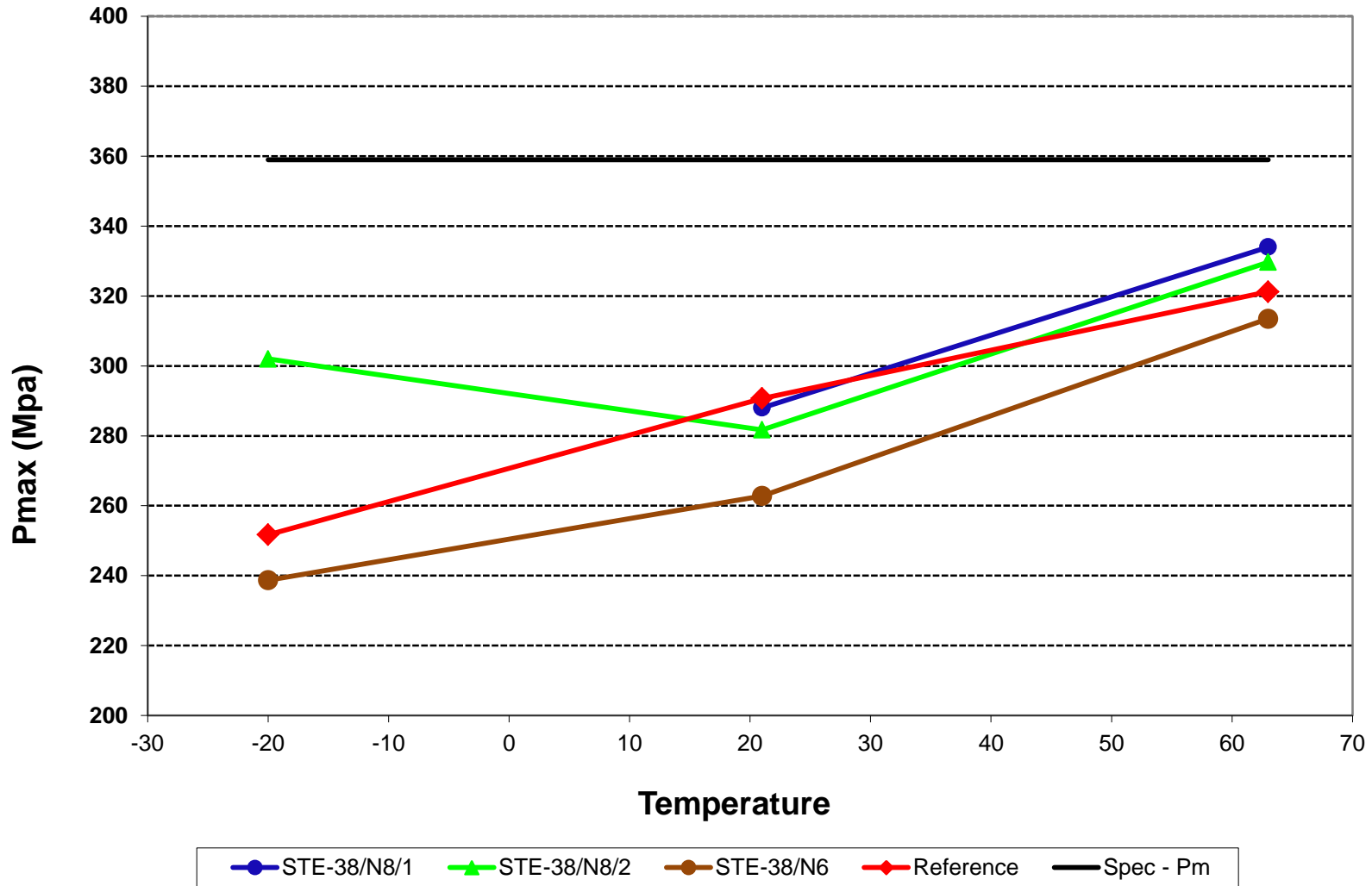


76mm Gun Firing: Vo versus Temperature - STE-38 and IP Formulations



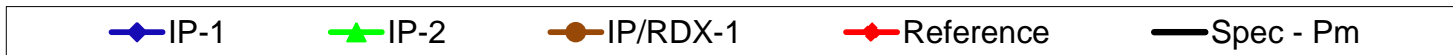
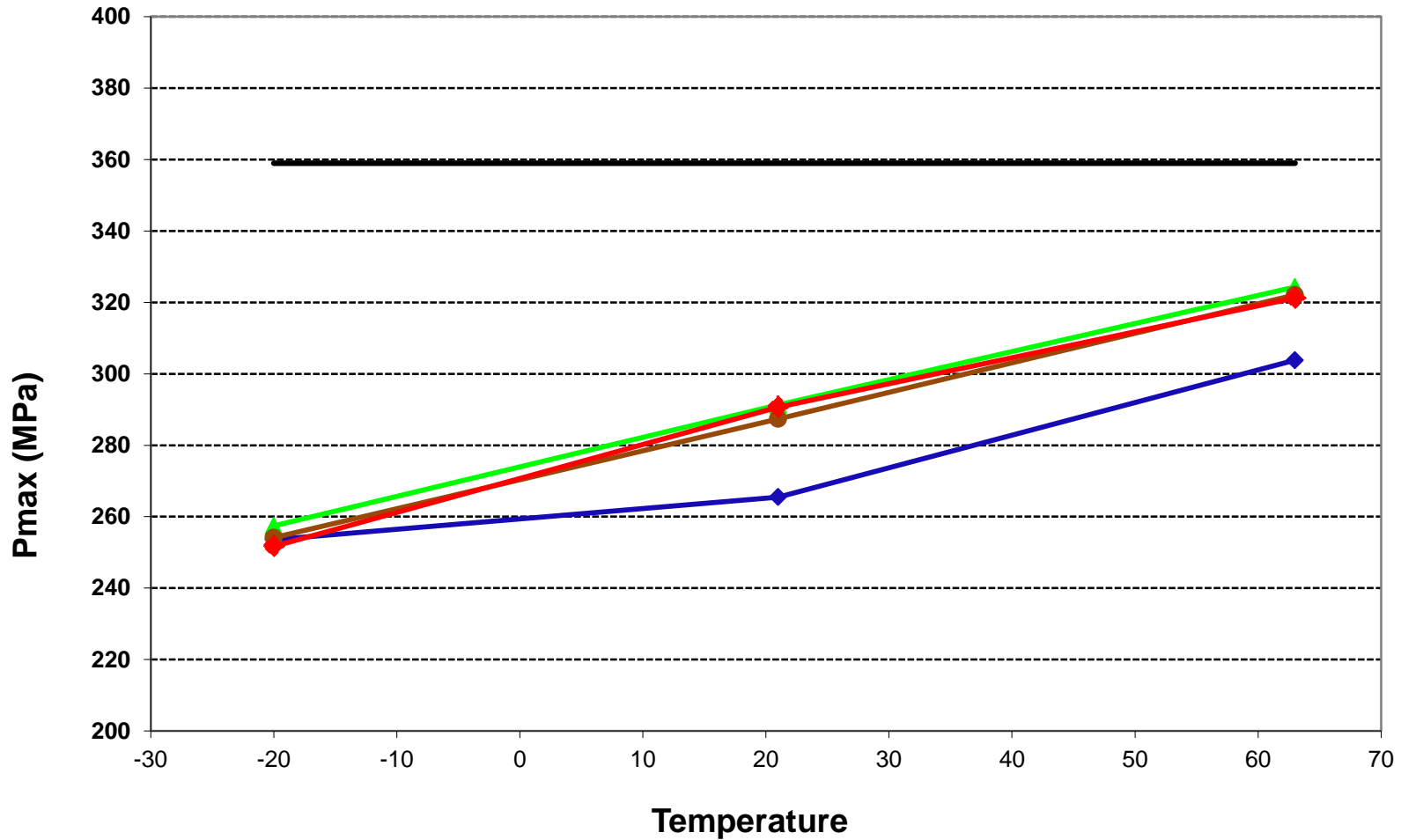


76mm Gun Firing: Pm versus Temperature - STE-38





76mm Gun Firing: Pmax versus Temperature - Inert Plasticer Formulations





Summary of 76mm Gun Firing Evaluation

- DEGDN and TEGDN formulations passed all IM tests but failed ballistically – exceeded 63°C pressure limit
- Traditional triple base formulation, STE-38, complies ballistically
- Single base formulation with inert plasticiser and formulation with RDX performed well ballistically
- Propellant processing and ballistic evaluation of the 3 alternative propellant formulations will continue
- The IM properties of the single base formulation with inert plasticiser and the formulation with RDX are unknown and had to be determined



IM Testing and Evaluation

IM tests performed on the candidate formulations were :

- Fragment impact test (STANAG 4496)
- Bullet impact test (STANAG 4241)
- Shape charge jet test (STANAG 4526)
- Slow cook-off test (STANAG 4382)
- Fast cook-off test (STANAG 4240)



Test Configuration – EMTAP Tubes with Propellant



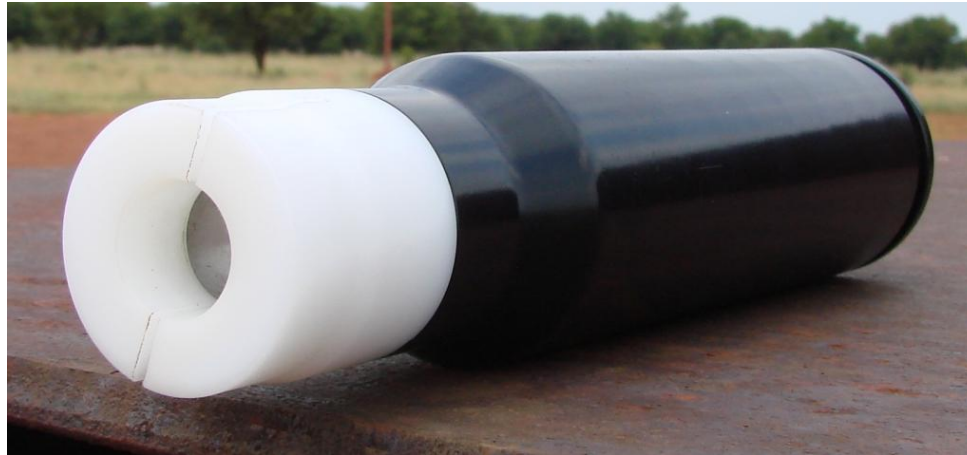
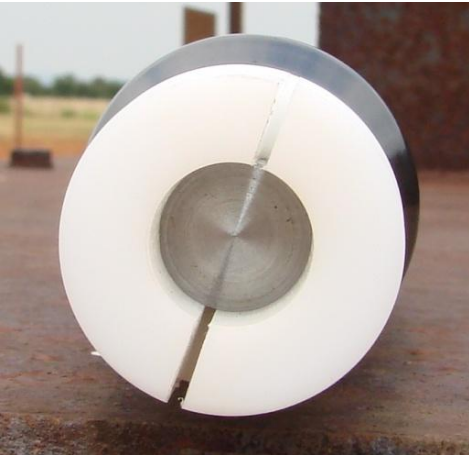


Description of Reaction Categories (STANAG 4491)

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 – Fragment Impact





Fragment Impact Test

IP-1



IP/RDX-1



STE-38/N8



TEGDN-P15





Test Configuration – Bullet Impact Test





Bullet Impact

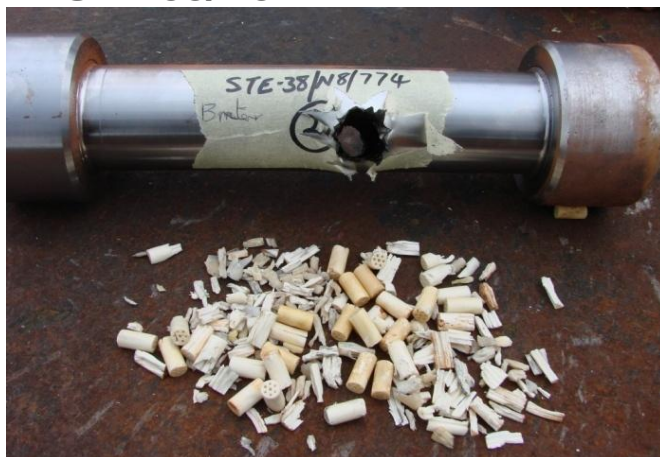
IP-1



IP/RDX-1



STE-38/N8

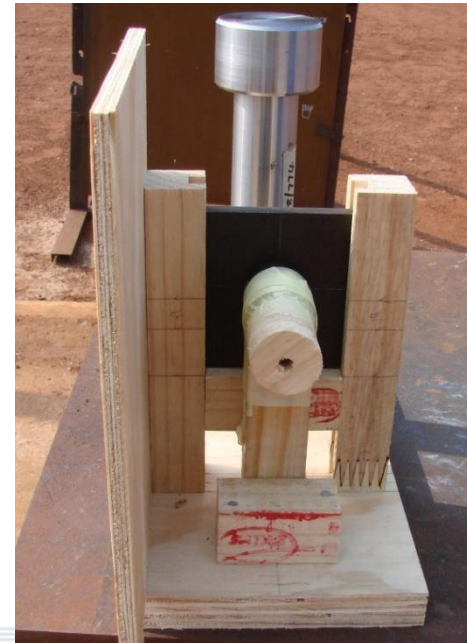


SSE





Test Configuration – Shape Charged Jet





Shape Charged Jet

IP-1



STE-38/N8



IP-2



IP/RDX-1



SSE Reference





Summary of IM Test Results

Propellant	Fragment Impact	Bullet Impact	Shape Charge Jet	Slow Cook-Off	Fast Cook-Off
TEGDN-P15	0/1	0	2	2	2
STE-38	0/1	0	2	2	2
IP-1	0/1	0	0/1	2	2
IP-2	0/1	0	2	2	2
IP/RDX-1	0/1	0	2	2	2
SSE Reference	0/1	0/1	2	2	2



Conclusions

- Different TEGDN/NC pastes were made and TEGDN/NC formulations were successfully processed solvent-less
- DEGDN and TEGDN formulations passed all IM tests but failed ballistically – exceeded 63°C pressure limit
- Traditional triple base formulation, STE-38, complies ballistically and passed initial comparative IM tests
- Single base formulation with inert plasticiser and formulation with RDX performed well ballistically and passed comparative IM tests
- Chemical stability testing has been performed according to STANAG 4582 and AOP-48, shelf-life > 10 years



Less Sensitive Replacement for SSE - Future Work

- Continue with ballistic evaluation
- Perform IM testing of final SSE replacement propellant formulations in fully assembled 76mm Naval rounds
- Make a final selection of replacement formulation based on ballistic and IM performance and other secondary factors
- Qualify the selected propellant formulation



Acknowledgements

- My colleagues from Z-Area at RDM North (Boskop) for performing the IM tests

and

- For the great reporting of the IM tests by means of photo's, video's and multi-media clips
- To Armscor for the partial funding of the project