IM Solutions For Projectiles Crimped to Cartridges for Artillery Application Insensitive Propellant

Christine M. Michienzi, Carl J. Campagnuolo,
Edward G. Tersine, Christine D. Knott

christine.michienzi@navy.mil

301-744-2554

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Background

- The PGU 44/B cartridge for the AC 130 aircraft consists of a cartridge case and a projectile that are crimped together
- Both components are IM sensitive

Munition	Platform	Propellant	Explosive	FCO	SCO	BI	FI	SD	SCJ
PGU 44/B	105mm Howitzer	M1	CompB	(I)	(I)	(I)	(I)	(I)	(I)

- Test data from ARL shows propellant alone still fails IM

Propelling charge w/ inert projectile		III	III	IV		III

- Separate effort to replace HE (Comp B → PBXN-109)
- This effort is to replace the M1 propellant in the M67 propelling charge with an insensitive propellant formulation

Background

- Insensitive propellant → NILE propellant
  - Improved IM over Navy's single base BS-NACO propellant
    - SCO → Type V reaction (Type III for BS-NACO)
    - FI → Type IV reaction (Type III for BS-NACO)
  - Similar properties to M1 used in 105-mm M67 round

Propellant	Impetus (J/g)	Covolume (cm^3/kg)	Gamma	Flame Temp (K)
M1	942	0.1076	1.271	2537
NILE	895	0.1190	1.279	2175

- Interior Ballistics (IB) Model developed using IBHVG2
  - Validated with data for current M1 propellant
  - Determined NILE grain geometry that would match M1 ballistic performance
  - Test data from initial gun test was in good agreement with IB model predictions except for:
    - M-11 "false" high pressure excursions in rounds where propellant beds were above primer tube and generated pressure waves.

Objectives For Second Gun Test

- Validate optimized interior ballistics model
- Test propellant performance at hot, cold and ambient temperatures
- Reconfigure the NILE propellant granulation(s) to reduce propellant bed height within the cartridge case
  - Verify the assumption that the charge configuration and non-ideal ignition was responsible for the pressure excursions

Optimized Interior Ballistics Model

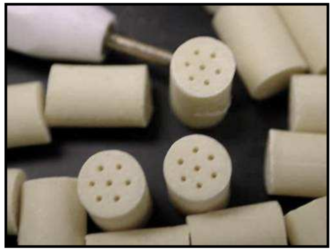
- Optimized IB model using IBHVG2 (lumped parameter 0-D code)
  - Validated with data for NILE propellant
  - Determined optimized granulation(s) for NILE propellant to be fired at cold (-50°F), ambient (70 °F) and hot (+145°F) conditions
  - Closed vessel burning rate data only available at “US Navy” temperatures (+20°F, +70°F and +120°F) – had to extrapolate (not ideal)

Optimized Propellant Granulation

- Optimized grain geometry of NILE determined for second engineering test
  - Dual granulation – maximize packing efficiency

Grain	Perf #	Length (in)	Outer Diameter (in)	Perf Diameter (in)	Web (in)	Specific Gravity	Recommended Charge Weight (lbm)
Optimized 1	7	0.075	0.075	0.010	0.011	1.589	1.94
Actual 1	7	0.081	0.070	0.010	0.010	1.578	1.95
Optimized 2	1	0.069	0.041	0.006	0.018	1.625	0.96
Actual 2	1	0.069	0.041	0.006	0.018	1.578	0.95

- Actual grains sizes manufactured – slightly different than optimal – not unusual
  - Swelling during extrusion
  - Shrinkage during drying



Test Configuration

- YUMA Proving Grounds - 105mm M102 Howitzer
- Data collection
  - Projectile muzzle velocity (dual Weibel radar)
  - Maximum breech pressure (M-11 copper crusher gauges)
- Spotter rounds fired first
  - Warm gun
  - Calibrate data collection systems
- Reduced charge NILE rounds
  - Fired at cold (-50℉), ambient (70℉) and hot (+14 5℉)
- Full charge NILE rounds
  - Fired at cold (-50℉), ambient (70℉) and hot (+14 5℉)

Test Configuration

Test Configuration

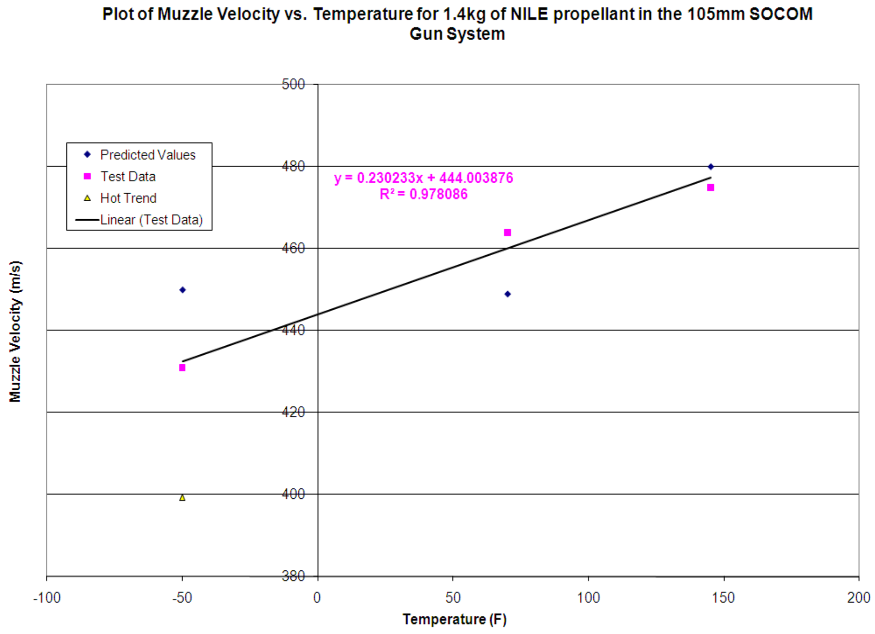
Test Matrix										
General						Propelling Charges			Data Collection	
Test No:	Test Date	Test Designation	QE (mil)	Projectile Type	Fuze type	Propellant Type	Charge Weight (kg)	Cond Temp (°F)	Weibel Radar	M-11 Gauges
1	9/1/09	Spotter 1	550	105H	M739A1	M1	1.279	AMB	Y	3
2	9/1/09	Spotter 2	550	105H	M739A1	M1	1.279	AMB	Y	3
3	9/1/09	Spotter 3	550	105H	M739A1	M1	1.279	AMB	Y	3
4	9/1/09	85% TCW - Amb	550	105H	M739A1	NILE	1.190	70	Y	3
5	9/1/09	100% TCW - Amb	550	105H	M739A1	NILE	1.400	70	Y	3
6	9/1/09	100% TCW - Amb	550	105H	M739A1	NILE	1.500	70	Y	3
7	9/1/09	100% TCW - Amb	550	105H	M739A1	NILE	1.525	70	Y	3
8	9/1/09	100% TCW - Amb	550	105H	M739A1	NILE	1.525	70	Y	3
9	9/1/09	100% TCW - Amb	550	105H	M739A1	NILE	1.525	70	Y	3
10	9/1/09	Clearing Round	550	105H	M739A1	M1	1.279	AMB	Y	3
11	9/2/09	Spotter 1	550	105H	M739A1	M1	1.279	AMB	Y	3
12	9/2/09	Spotter 2	550	105H	M739A1	M1	1.279	AMB	Y	3
13	9/2/09	Spotter 3	550	105H	M739A1	M1	1.279	AMB	Y	3
14	9/2/09	70% TCW - Hot	550	105H	M739A1	NILE	1.110	145	Y	3
15	9/2/09	100% TCW - Hot	550	105H	M739A1	NILE	1.400	145	Y	3
16	9/2/09	100% TCW - Hot	550	105H	M739A1	NILE	1.500	145	Y	3
17	9/2/09	100% TCW - Hot	550	105H	M739A1	NILE	1.500	145	Y	3
18	9/2/09	Clearing Round	550	105H	M739A1	M1	1.279	AMB	Y	3
19	9/3/09	Spotter 1	550	105H	M739A1	M1	1.279	AMB	Y	3
20	9/3/09	Spotter 2	550	105H	M739A1	M1	1.279	AMB	Y	3
21	9/3/09	Spotter 3	550	105H	M739A1	M1	1.279	AMB	Y	3
22	9/3/09	100% TCW - Cold	550	105H	M739A1	NILE	1.400	-50	Y	3
23	9/3/09	100% TCW - Cold	550	105H	M739A1	NILE	1.525	-50	Y	3
24	9/3/09	100% TCW - Cold	550	105H	M739A1	NILE	1.525	-50	Y	3
25	9/3/09	Clearing Round	550	105H	M739A1	M1	1.279	AMB	Y	3

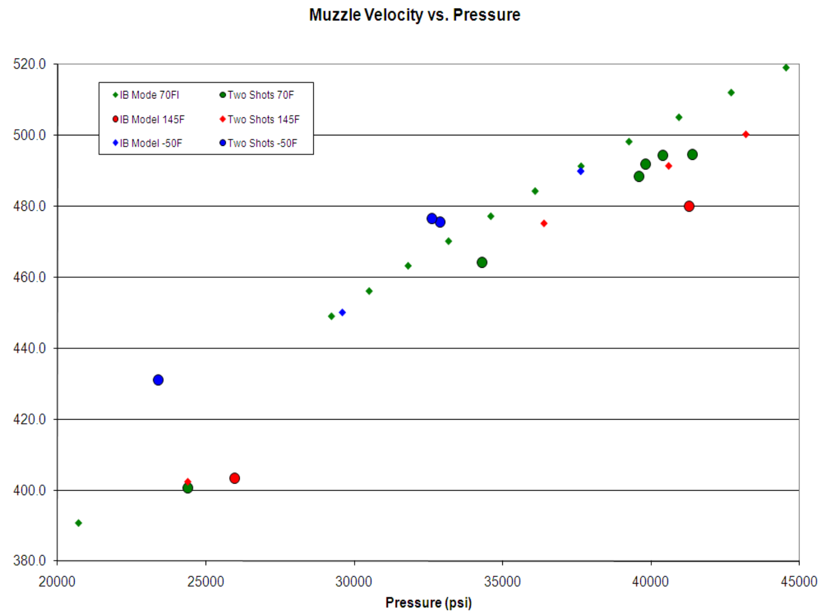
Test Configuration

Test Predicted and Actual Performance								
General					Predicted Performance		Actual Performance	
Test No:	Test Date	Test Designation	Charge Weight (kg)	Cond Temp (°F)	Muzzle Velocity (ft/s)	Max Breech Pressure (psi)	Avg. Muzzle Velocity (ft/s)	Avg. Max Breech Pressure (psi)
1	9/1/09	Spotter 1	1.279	AMB	1522	35090	1626	36900
2	9/1/09	Spotter 2	1.279	AMB	1522	35090	1622	38000
3	9/1/09	Spotter 3	1.279	AMB	1522	35090	1621	37000
4	9/1/09	85% TCW - Amb	1.190	70	1282	20704	1315	24400
5	9/1/09	100% TCW - Amb	1.400	70	1473	29290	1523	34300
6	9/1/09	100% TCW - Amb	1.500	70	1566	34597	1602	39600
7	9/1/09	100% TCW - Amb	1.525	70	1599	36731	1614	39800
8	9/1/09	100% TCW - Amb	1.525	70	1599	36731	1623	41400
9	9/1/09	100% TCW - Amb	1.525	70	1599	36731	1622	40400
10	9/1/09	Clearing Round	1.279	AMB	1522	35090	1617	36700
11	9/2/09	Spotter 1	1.279	AMB	1522	35090	1663	39900
12	9/2/09	Spotter 2	1.279	AMB	1522	35090	1645	39700
13	9/2/09	Spotter 3	1.279	AMB	1522	35090	1644	39600
14	9/2/09	70% TCW - Hot	1.110	145	1323	25963	1320	24400
15	9/2/09	100% TCW - Hot	1.400	145	1575	41267	1559	36400
16	9/2/09	100% TCW - Hot	1.500	145	1665	49619	1641	43200
17	9/2/09	100% TCW - Hot	1.500	145	1667	49619	1612	40600
18	9/2/09	Clearing Round	1.279	AMB	1522	35090	1647	40400
19	9/3/09	Spotter 1	1.279	AMB	1522	35090	1578	32300
20	9/3/09	Spotter 2	1.279	AMB	1522	35090	1563	27800
21	9/3/09	Spotter 3	1.279	AMB	1522	35090	1575	29700
22	9/3/09	100% TCW - Cold	1.400	-50	1476	29580	1414	23400
23	9/3/09	100% TCW - Cold	1.525	-50	1608	37613	1561	32900
24	9/3/09	100% TCW - Cold	1.525	-50	1608	37613	1564	32600
25	9/3/09	Clearing Round	1.279	AMB	1522	35090	1576	29300

Test Data

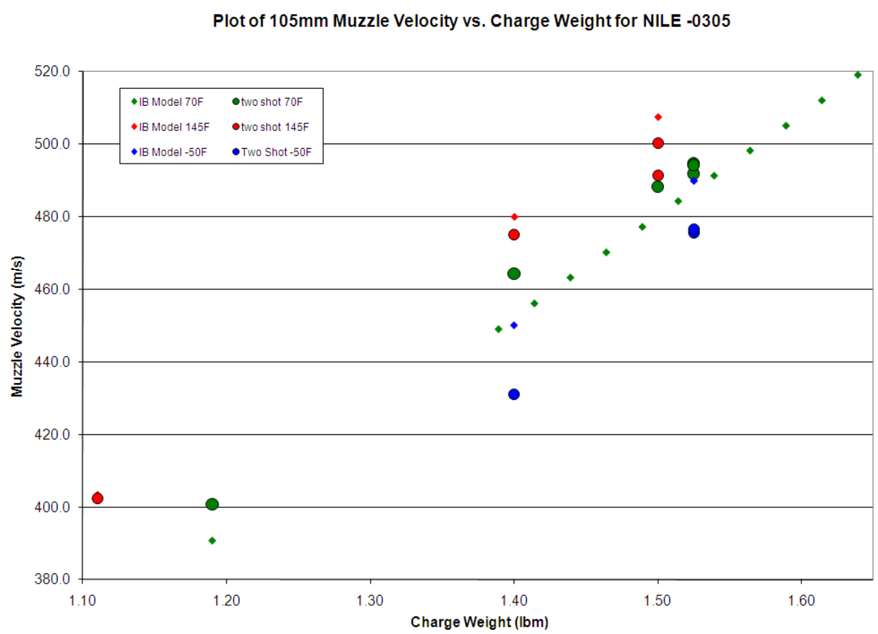
- Smooth, consistent correlation of maximum chamber pressure and projectile muzzle velocity
  - No pressure waves or perceived pressure excursions
- Temperature dependence of Muzzle Velocity is low

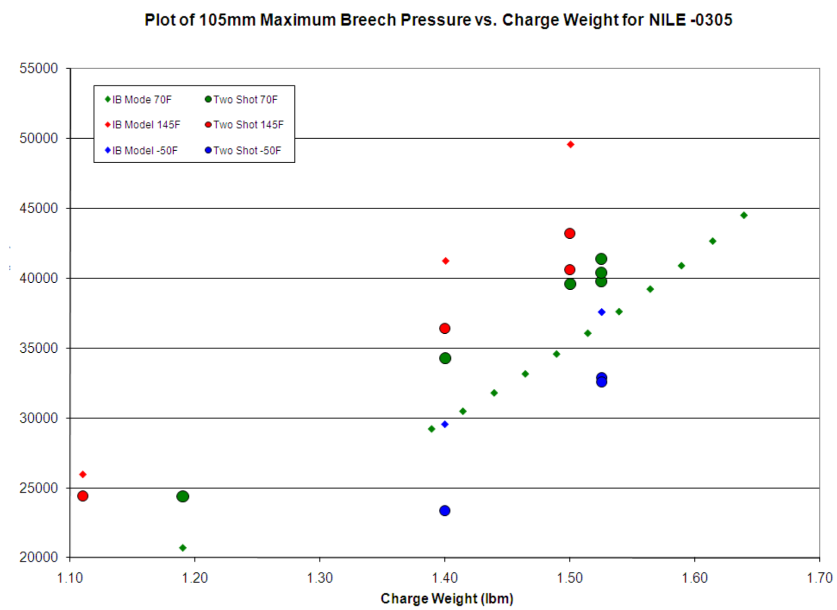




Test Data

- Muzzle velocity is in agreement with IB model predictions
- Maximum Chamber Press agreement with IB model predictions*
- Used standard igniter – not optimized for NILE





* Hot and cold NILE propellant burning rates extrapolated from data at 20°F and 120°F

Conclusions and Future Work

- Second test of NILE in 105-mm howitzer showed improved performance
- Further optimization of the propellant granulation is necessary
- Ignition device redesign is necessary.
  - Energetic material replacement → robust NILE ignition and more insensitive than black powder
  - Optimize ignition device output (P vs. t)
- Testing of NILE propelling charge to demonstrate IM improvements