Qualification Testing of the Insensitive TNT Replacement Explosive IMX101

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Introduction

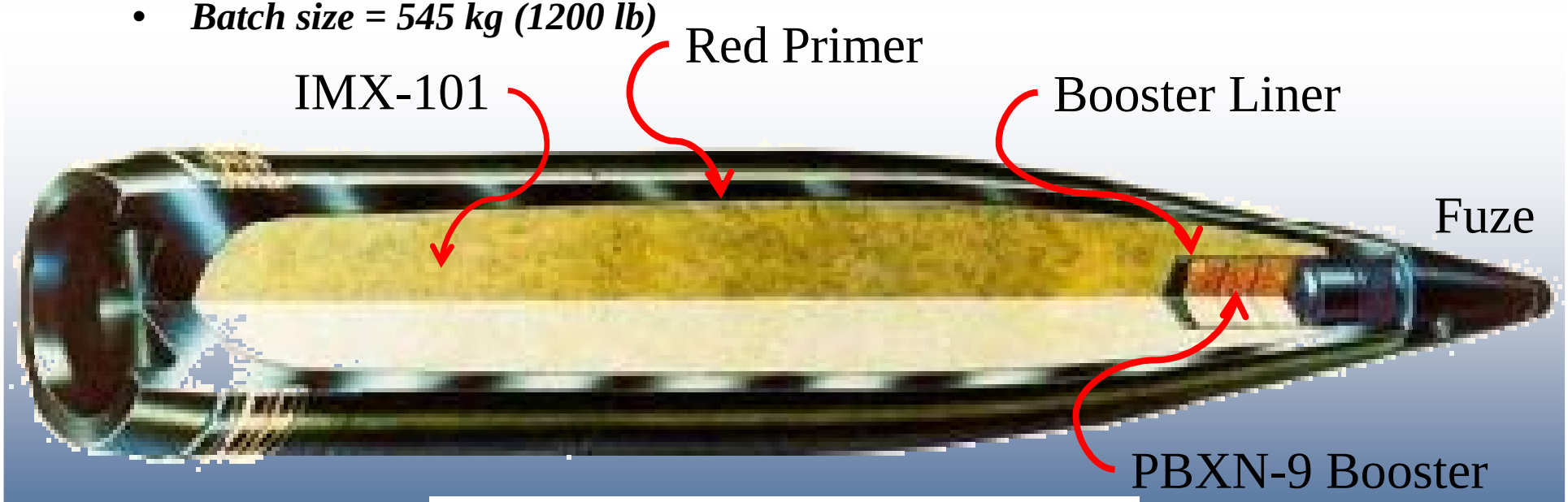
- **PM CAS initiated Common Low-cost Insensitive Munitions Explosive Program for affordable TNT and Comp B Replacement for near term insertion**
  - **Goal was to select one common candidate or one for TNT and one for Comp B energy**
  - **Identified domestic and international candidates**
  - **Based on 23 candidates evaluated, IMX-101 selected as TNT replacement**

- **Overall Program Objectives:**
  - **Joint Army/USMC program for artillery munitions**
  - **Funding from: OSD-Technology Transition Office, OSD - Joint IM Technical Program Office, PEO AMMO, USMC, PM CAS**

- **Accelerated Implementation of Hazard Division reduction and IM Solution in M795 155mm Artillery Ammunition to the Warfighter**

M795 155mm Artillery Round

- ***IMX-101 Formulation in the M795 155mm Artillery Round***
  - ***Formulated from available ingredients***
  - ***Detonation energy equivalent to TNT***
  - ***Low hazard sensitivity***
  - ***Melt Pour processing similar to TNT***
  - ***Over 60,000 kg (132,000 lbs) produced to date***
    - ***Batch size = 545 kg (1200 lb)***

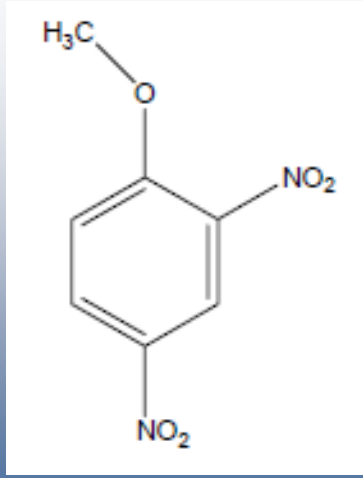


M795 155mm Artillery Round

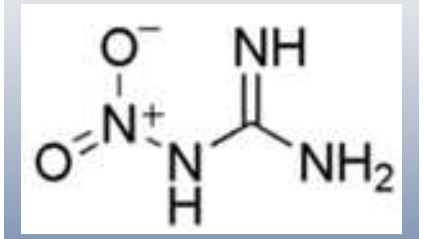
IMX-101

➢ ***IMX-101 Formulation***

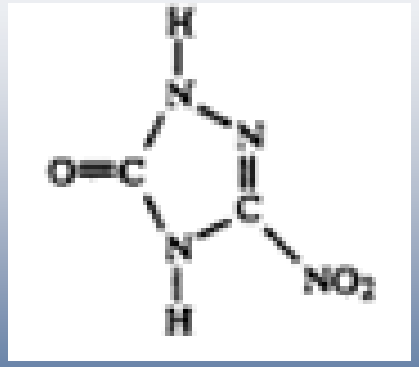
	IMX-101	TNT	Comp B
2,4-Dinitroanisole (DNAN)	43.5 (±2)	--	--
Nitroguanidine (NQ)	36.8 (±2)	--	--
3-Nitro-1,2,4-triazol-5-one (NTO)	19.7 (±2)	--	--
Trinitrotoluene (TNT)	--	100	40
RDX	--	--	60



DNAN



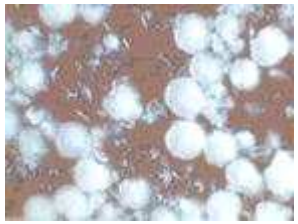
NQ



NTO

Making the IM Mission Possible

- Achieving the IM Mission Required New Technologies
- Energetic and Critical Materials for IM / EM Applications
  - DNAN
  - NTO
  - TATB
  - High Bulk Density NQ
  - FEM RDX and HMX
  - DMDNB
  - “Special Grade” RDX
  - R8002 Energetic Plasticizer



NTO Crystals

Nutsches of TATB

Incorporation of DNAN in IMX-101

2,000 gallon Glass-lined Reactor

- All Materials Produced on a True Production Scale at HSAAP

IM Melt Cast Explosives from Holston AAP

IMX-101	DNAN & NTO based formulation. Selected by the Army as the common TNT replacement. Applications include 105mm, 120mm, & 155 mm munitions.
IMX-104 (aka OSX-7)	Contains DNAN, NTO, and RDX in various grades. Selected by the Army as the common Comp B replacement in IM Mortar systems (60mm, 81mm, & 120mm) and various submunitions.
OSX-8	Contains DNAN, NTO, and HMX in various grades and provides excellent IM and energetic performance properties. Being evaluated in 60mm Mortar (Europe) and 120mm HET Tank Ammo (FMS).
OSX-12	An aluminized version of IMX-104 which offers excellent IM properties combined with high blast energetic output.
PAX-21	DNAN based melt-cast explosive which is currently qualified and fielded in the U. S. Army 60mm Mortar system.
PAX-41	DNAN based melt-cast explosive which is currently qualified and fielded in the U. S. Army Spider Munitions system.

IMX-101 Qualification

- ***DoD Energetic Materials Qualification Process***

Test Protocol: (1) Allied Ordnance Publication Seven (AOP-7) (Edition 2 Rev. 3), "Manual of Data Requirements and Tests for the Qualification of Explosive Materials for Military Use", December 2007.

(2) Standardization Agreement (STANAG) 4170 (Edition 3), "Principles and Methodology for the Qualification of Explosive Materials for Military Use", 2007.

(3) DoD Energetics Qualification Program Matrix for Main Charge Explosives

- Comprehensive assessment of the Energetic Material
  - Safe and Suitable for the intended use
  - Test Protocols Coordinated with NOSSA

IMX-101 Qualification

- *IMX-101* Lot# BAE07K375-007 (unless noted otherwise)

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULT (RDX AND TNT)	COMMENT
1.0	**STABILITY CHARACTERIZATION**						
1.1	Vacuum Thermal Stability (VTS or MVTS)	MIL-STD-1751A (1061 or 1063) Or STANAG 4556	5.00±0.05g 100°C/48 h Or 100°C/40 h	? 2 ml/g of gas evolved	0.50 ml/g (100°C/48 h) 0.34 ml/g (100°C/40 h)	RDX: 0.12 TNT: 0.10 ml/g	
1.2	Thermal Stability at +75C	TB 700-2 UN Test 3c	50g 75°C/48 h	Evidence of Self Heating	No Reaction	RDX: No Reaction TNT: No Reaction	

IMX-101 Qualification

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULT (RDX AND TNT)
2	**THERMAL CHARACTERIZATION**					
2.2	DSC	MIL-STD-1751A (1072) Or STANAG 4515	20 mg 10 °C/min	Endotherm(s): Exotherm(s): Onset Temps Peak Temps	Endotherm: 95 °C Exotherm: Onset: 212 °C Peak: 223 °C	RDX: Endotherm: 205 °C Exotherm: Onset: 210 °C Peak: 241 °C TNT: Endotherm: 77 °C Exotherm: Onset: Peak: 300 °C

IMX-101 Qualification

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULT (RDX AND TNT)
3	**COMPATIBILITY (Ingredients and Contact Materials)**					
3.1	VTS	MIL-STD-1751A (1061 or 1063) Or STANAG 4556	5.00±0.05g 100 °C/48 h Or 100 °C/40 h	Excess Gas: ≤ 2 ml/g of gas evolved	IMX-101 & M795 Metal = 0.14 ml/g IMX-101 & Booster liner = 0.27 ml/g IMX-101 & Red Primer = 0.07 ml/g IMX-101 & RTV Silicone (DC 3140) = 0.44 ml/g IMX-101 & Al = 0.87 ml/g IMX-101 & PBXN-9 = 0.28 ml/g	IMX-101 = 0.50 ml/g (100 °C/48 h)

IMX-101 Qualification

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULT (RDX AND TNT)
4	**IGNITION TEMPERATURE**					
4.2	Woods Metal Bath (5-sec explo temp) †	MIL-STD-650 (515.1)	40 mg Temperatures near Decomposition	Time to Explosion Temperatures over range 0.5-s to 9.0-s	262 °C	RDX: 227-252 °C TNT: 327 °C
4.3	Henkin Time to Explosion	Gibbs, T. and Popolato, A. (ed.), "LASL Explosive Property Data," p. 231, University of California Press, Berkeley, CA	40 mg Temperatures near Decomposition	Time to Explosion (t_e) and Explosion Temperature (T_e)	ARL: 218 °C USAF: 209 °C 4 NO GO at 2000 sec	RDX: 215 °C TNT: 286 °C
4.4	Critical Temperature Calculation (Tc) *	MIL-STD-1751A (1074)	Kinetic Data obtained from variable heating rate DSC. Experimental Tc from 4.3 results	Tc > 82 °C at any size. Time to explosion at 82 °C exceeds 500 days	Tc: 1-liter geometry ARDEC: 105 °C ARL: 107 °C BAE: 112 °C BAE ARC: 151 °C	RDX: 149 °C TNT: 160 °C Comp B = 136 °C

†Lot# BAE07K375-006

*DSC derived kinetic data results in low Tc estimate, see 5.5

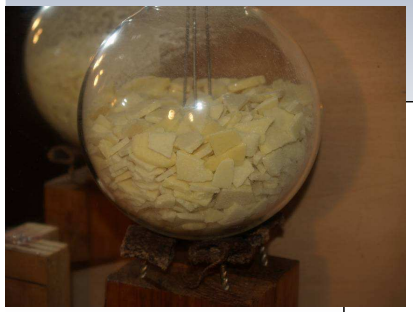
IMX-101 Qualification

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULT (RDX AND TNT)
5	**EXPLOSIVE RESPONSE WHEN IGNITED**					
5.2	Variable Confinement (FCO & SCO)	STANAG 4491	50 g FCO = ~10 °C/s SCO = 3.3 °C/hr	Burn to Deflagration Transition	**FCO** T15: Burn T30: Burn T45: Burn T60: Burn **SCO** T15: Burn T30: Burn T45: Pres Rupture T60: Pres Rupture	Comp A5 (98.5% RDX); **FCO** T15 = detonation **SCO** T15 = partial detonation
5.4	Small-Scale Burn Test	TB 700-2 UN Test 3d	Two 10 g and Two 100 g trials	Explosion = Failure	No Explosion Pass	RDX: TNT: Pass
5.5	1-liter Spherical Cook Off Test ††	MIL-STD-1751A (1075)	Sample is heated from melt point at 3.3 °C/hr until decomposition	Minimum margin of safety for processing is Tc ≥ 30 ℃ above desired processing temperature	Tc: ARL: 145 °C USAF: 139 °C	RDX = 154 °C TNT = 211 °C Comp B = 143 °C IMX-101 at 12-liter; Tc = 148 °C

†† Lot# BAE07K375-002

IMX-101 Qualification

- *Critical Temperature – Behavior upon Scale up*
  - *Critical temperature does not decrease with increasing explosive mass*



IMX-101 Qualification

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULT (RDX AND TNT)
6	**ELECTROSTATIC SENSITIVITY**					
6.1	Small-Scale ESD Test †	MIL-STD-1751A (1032) STANAG 4490	30 mg "No Go" 20 trials 0.25 J	Not more sensitive than Comp B (ρ = 1.65 g/cc)	No Go	RDX: Go @ 0.25 J TNT: No Go @ 0.25 J
7	**IMPACT SENSITIVITY**					
7.1	ERL/Bruceton †	MIL-STD-1751A (1012)	35 mg 2.5 kg drop weight 50% Point	Not more sensitive than Comp B (ρ = 1.65 g/cc)	> 100 cm	RDX: 18 cm TNT: 88 cm
8	**FRICTION SENSITIVITY**					
8.1	BAM ††	TB 700-2 UN Test 3(b)(ii)	Sample Config = 10 mm^3 "No Go" six trials 80 N Min	Not more sensitive than Comp B (ρ = 1.65 g/cc)	240 N	RDX: 168 N TNT: 216 N Comp B : 112N

†Lot# BAE07K375-006 **††Lot# BAE07K375-002**

RDX =Type I or II, Class 5 RDX conforming to MIL-DTL-398

IMX-101 Qualification

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULT (RDX AND TNT)
9	**SHOCK SENSITIVITY**					
9.1	NOL Large-Scale Gap Test (LSGT)	MIL-STD-1751A (1041)	Sample Config = 37 mm (ID) x 140 mm (L) 50% point	Not more sensitive than Comp B (ρ = 1.65 g/cc)	Critical Diameter too large Go to 9.5	RDX: 323 cards, 7.4 kbar, ρ = 1.64 g/cc Comp B: 210 cards, 19 kbar, ρ = 1.69 g/cc TNT: 153 cards, 37 kbar, ρ = 1.60 g/cc
9.4	EIDS Gap Test†††	TB 700-2 UN Test 7(b)	Sample Config = 73 mm (ID) x 280 mm (L) with a 70 mm gap "no go" 3 trials	"No Go" = no witness plate penetration	Pass ρ = 1.65 g/cc	RDX: NA TNT: NA
9.5	Expanded Large-Scale Gap Test (ELSGT)	MIL-STD-1751A (1043)	Sample Config = 73 mm (ID) x 280 mm (L) 50% Point	Not more sensitive than Comp B (ρ = 1.65 g/cc)	158 cards, 59 kbar ρ = 1.64 g/cc	Comp B: 489 cards, 10 kbar, ρ = 1.69 g/cc TNT: 457 cards, 14 kbar, ρ = 1.59 g/cc
9.8	Cap Sensitivity	TB 700-2 UN Test 7(a)	Sample Config = 80 mm (ID) x 200 mm (L) "no go" 3 trials	"No Go" = no witness plate penetration	Pass	RDX: GO TNT: Pass

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††† **Lot# BAE08K375-010**

IMX-101 Qualification

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULT (RDX AND TNT)
10	**OTHER SENSITIVITIES**					
10.1	Set-Back Sensitivity	Local Protocol ARDEC Test Method	20 g Sample Config = 13 mm (ID) x 95 mm (L)	Pass = "no go" to 95% confidence level	15,000 G Gap = 4.4-mm No Reaction Pass	15,000 G TNT Gap = 2.7-mm Comp B Gap = 2.1-mm
10.2	Friability Test	TB 700-2 UN Test 7(c)(ii), 7(d)(ii)	9 g Sample Config = 18 mm (D)	Fail = dp/dt of ignited powder is ≥ 15 MPa/ms	See Susan Test Go to 15.1	
10.3	Explosivity of Dust ††	ASTM Method E1515-98	Powder ≥ 95% minus 200 mesh	Lowest concentration of dust for which the pressure ratio (PR) ≥ 2 is the MEC	800-900 g/m^3	RDX: 300 to 400 g/m^3 TNT: 100 to 200 g/m^3

†† **Lot# BAE07K375-002**

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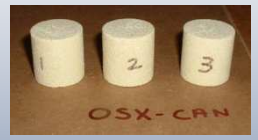
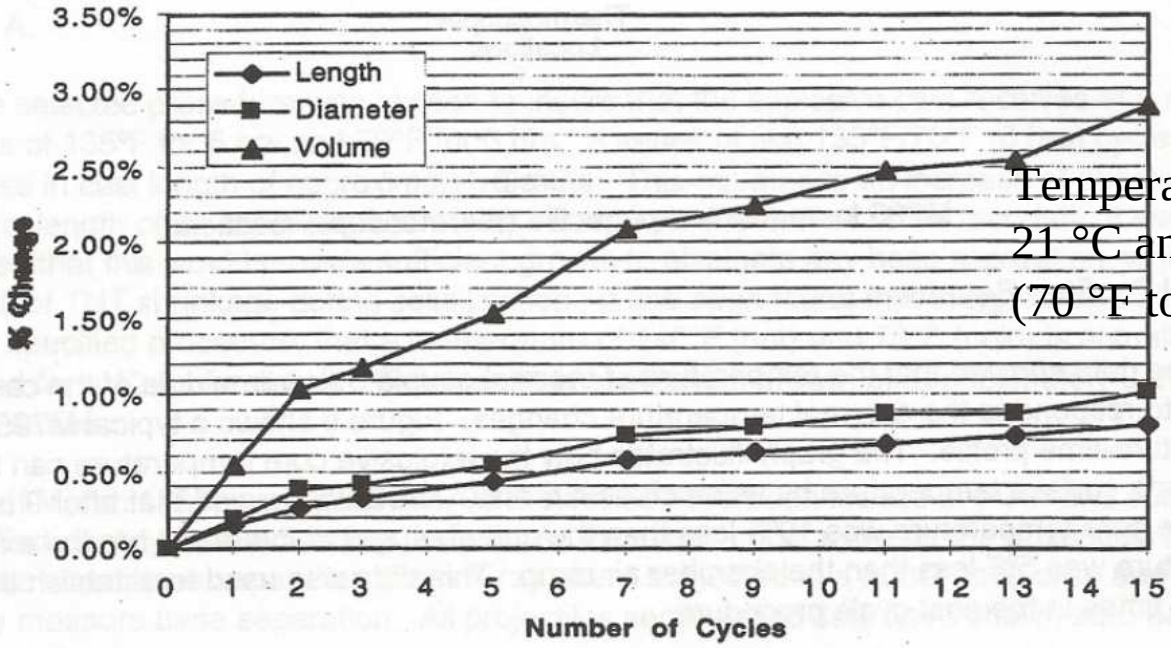
IMX-101 Qualification

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULT (RDX AND TNT)
11	**CHEMICAL, PHYSICAL, AND MECHANICAL PROPERTIES**					
11.2	Coefficient of Thermal Expansion	ASTM D696	200 mg	No Range or Limit	20 x 10^{-6} m/m-K	RDX: 64 x 10^{-6} m/m-K TNT: 50 x 10^{-6} m/m-K
11.4	Compressive Strength	STANAG 4443	Solid Sample Sample Config L/D =1	No Range or Limit	2780 psi (65 °C, 1.5 in./sec) 3710 psi (25 °C, 1.0 in./sec) 3480 psi (-45 °C, 1.0 in./sec)	TNT: 1000 psi (60 °C, 1.5 in./sec) 2200 psi (25 °C, 1.0 in./sec) 4200 psi (-45 °C, 1.0 in./sec)
11.10	Density/Bulk Density	MIL-STD-286C (510.3.1)	25 g	No Range or Limit	Pycnometer = 1.67 g/cc Bulk Density = 0.82 g/cc Cast Density = 1.64 g/c	TNT Bulk Density = 0.80 g/cc Cast Density = 1.64 g/cc
11.11	Growth 	AOP-7 MIL-STD-1751A (1162)	Sample Config = 25 mm (D) x 25 mm (L). 30 cycles at -54 °C (-65 °F) and 71 °C (+160 °F).	≤ 1.0 %	8%	TNT: 3% (over temp range 21 °C to °60 C) Comp B: +8.5% PBX-9502: 1.5 – 3.2%
11.12	Exudation	AOP-7 MIL-STD-1751A (1161)	Sample Config = 25 mm (D) x 125 mm (L). 71 °C (+160 °F) for 320 hr.	≤ 0.1%	0.05%	TNT: 0.673%

Explosive Irreversible Growth

TNT Growth: Data not available per 1751A protocol

Figure 7 illustrates that additional cycles will result in continued pellet growth. The data showed that during the prescribed tests, pellet growth approaching 3% of the total volume was achieved.



Temperature Range:
21 °C and 60 °C
(70 °F to 140 °F)

From: "Post Cycle Temperature Conditioning for the M795 155-mm Projectile", ARWEC-TR-98011, December 1998

TNT irreversible growth is used as a process aid to improve quality of the cast and TNT adhesion to the shell

IMX-101 Qualification

Growth Supplemental Information – Rounds Aged and Fired

Number of Rounds	Temperature Condition (°C)	Humidity Condition (%RH)	Number of Days	Number of Cycles	Gun Pressure Condition	Result
30	33 to 71	80 - 14	7	7	Max Service	All Pass
30	-51		7		Max Service	All Pass
60	33 to 71	80 - 14	28	28	Max Service	All Pass
60	-51		14		Max Service	All Pass
16	30 to 60	95	10	10	Max Service	All Pass
16	30	95	28		Max Service	All Pass
1	75		2		Max Service	Pass

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Temperature cycled rounds launched without incident and functioned as expected

IMX-101 Qualification

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULT (RDX AND TNT)
12	**VARIATION OF PROPERTIES WITH AGE PROTOCOL**					
12.1	Variation of Properties with Age	NAVSEAINST 8020.5C AOP-7	60 °C (140 °F) Sealed Container. Sample at 0,1,2,4,6,8, months. 70 °C (158 °F), Sealed Container. Sample at 0,1,2,4,6 months. 25 °C (77 °F), and 30% RH Sample at 0,12 months. Tests: 1.2, 2.2, 4.3, 7.1, 8.1, 9.5	See Specific Test Ranges and Limits for Tests: 1.2, 2.2, 4.3, 7.1, 8.1, 9.5	See Aging Table Below No significant variation from baseline results	See references for Tests: 1.2, 2.2, 4.3, 7.1, 8.1, 9.5

IMX-101 Qualification

Aged 60 °C, Sealed Container

Month	DSC (2.2)	ERL Impact (7.1)	BAM Friction (8.1)	ESD (6.1)	ELSGT (9.5)
0	Endotherm: 95 °C Exotherm: Onset: 212 °C Peak: 223 °C	> 100 cm	168 N	No Go @ 0.25 J	158 cards, 59 kbar ρ = 1.64 g/cc
1	Exotherm: Onset: 202 °C	> 100 cm	96 N	No Go @ 0.25 J	
2	Exotherm: Onset: 201 °C	> 100 cm	96 N	No Go @ 0.25 J	
4	Exotherm: Onset: 204 °C	> 100 cm	160 N	No Go @ 0.25 J	150 cards, 61 kbar ρ = 1.65 g/cc
6	Exotherm: Onset: 202 °C	> 100 cm	160 N	No Go @ 0.25 J	
8	Exotherm: Onset: 196 °C	> 100 cm	168 N	No Go @ 0.25 J	148 cards, 61 kbar ρ = 1.65 g/cc

IMX-101 Qualification

Aged 70 °C, Sealed Container

Month	DSC (2.2)	ERL Impact (7.1)	BAM Friction (8.1)	ESD (6.1)	ELSGT (9.5)	Compressive Strength (11.4)
0	Endotherm: 95 °C Exotherm: Onset: 212 °C Peak: 223 °C	> 100 cm	168 N	No Go @ 0.25 J	158 cards, 59 kbar ρ = 1.64 g/cc	2200 psi (25 °C, 1.0 in./sec)
1	Exotherm: Onset: 207 °C	> 100 cm	108 N	No Go @ 0.25 J		
2	Exotherm: Onset: 206 °C	> 100 cm	108 N	No Go @ 0.25 J		
3	Exotherm: Onset: 201 °C	> 100 cm	108 N	No Go @ 0.25 J	166 cards, 58 kbar ρ = 1.65 g/cc	
4	Exotherm: Onset: 198 °C	> 100 cm	160 N	No Go @ 0.25 J		
6	Exotherm: Onset: 200 °C	> 100 cm	160 N	No Go @ 0.25 J	174 cards, 56 kbar ρ = 1.65 g/cc	2900 psi (25 °C, 1.0 in./sec)

IMX-101 Qualification

Aged 25 °C and 30% RH

Month	DSC (2.2)	ERL Impact (7.1)	BAM Friction (8.1)	ESD (6.1)	ELSGT (9.5)	Compressive Strength (11.4)
0	Endotherm: 95 °C Exotherm: Onset: 212 °C Peak: 223 °C	> 100 cm	168 N	No Go @ 0.25 J	158 cards, 59 kbar ρ = 1.64 g/cc	2200 psi (25 °C, 1.0 in./sec)
12	Endotherm: °C Exotherm: Onset: 203 °C Peak: 211 °C	> 100 cm	216 N	No Go @ 0.25 J	135 cards, 64 kbar ρ = 1.65 g/cc	3140 psi (25 °C, 1.0 in./sec)

Aged Composition				
Month	Temperature (^{o}C)	DNAN (%)	NQ (%)	NTO (%)
0	NA	43.5	36.8	19.7
6	70	43.1	36.6	19.1
8	60	43.5	35.4	20.6

Additional Testing:
Cube Cracking: 30/60 days at 60ºC, 6” cubes
Result: No change from XRAY analysis

IMX-101 Qualification

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULT (RDX AND TNT)
13	**TOXICITY EVALUATAION**					
13.1	Products of Combustion/Detonation	Calculation from CHEETAH	Explosive Formulation	No Range or Limit	See CHEETAH Products of Detonation Table Below	See Comparison with RDX and TNT in Tables Below
13.2	Other Toxicity Data as Needed	MIL-STD-1751A (4.6.6)	Assessments of ingredients not previously examined, combustion products, and by-products of the processing of the explosive	Ranges and Limits are defined within individual test methods and reference publications	LD_{50}: (mg/kg) IMX101: 1088 DNAN: 199 NQ: 10,200 NTO: >2000	LD_{50}: (mg/kg) RDX: 100 TNT: 660 - 1320

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IMX-101 Qualification

Calculated Products of Detonation
Cheetah 5.0 Standard Run

1) IMX-101 @ density = 1.64 g/cc (% TMD = 96.6)

Product Concentrations

Name	Phase	(mol/kg)	(mol/mol explosive)
n2	Gas	1.249e+001	1.688e+000
h2o	Gas	9.264e+000	1.252e+000
co2	Gas	5.493e+000	7.423e-001
ch4	Gas	2.238e+000	3.024e-001
co	Gas	2.009e+000	2.715e-001
nh3	Gas	4.651e-001	6.285e-002
h2	Gas	3.853e-001	5.207e-002
chno	Gas	1.192e-001	1.611e-002
c2h6	Gas	9.942e-002	1.344e-002
c2h4	Gas	3.021e-002	4.082e-003
ch3oh	Gas	9.310e-003	1.258e-003
c3h8	Gas	4.148e-003	5.605e-004
ch2o2	Gas	2.541e-003	3.434e-004
acetone	Gas	5.369e-004	7.255e-005
c2h6o	Gas	1.895e-004	2.561e-005
c2h2	Gas	1.368e-004	1.848e-005
hcn	Gas	2.455e-005	3.317e-006
h	Gas	6.771e-006	9.149e-007
no	Gas	2.980e-007	4.026e-008
benzene	Gas	7.800e-009	1.054e-009
n2o	Gas	2.930e-009	3.960e-010
*c	graphite	1.091e+001	1.474e+000
Total Gas		3.261e+001	4.407e+000

IMX-101 Qualification

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULT (RDX AND TNT)
14	**PERFORMANCE PROPERTIES**					
14.1	Detonation Velocity	MIL-STD-1751A (1101)	Cast rod having a diameter greater than critical. Recommend L/D ≥ 3. Bare or confined.	No Range or Limit	6.9 km/s (ρ = 1.64 g/cc)	RDX: 8.1 km/s (ρ = 1.6 g/cc) TNT: 6.9 km/s (ρ = 1.64 g/cc)
14.2	Critical Diameter	MIL-STD-1751A (1091)	A series of cylindrical charges of different diameters having the same physical properties and prepared from one uniform batch of explosives	No Range or Limit	64-mm – 68-mm	RDX: 0.5-mm TNT: 2.0-mm
14.5	Detonation Pressure	Plate Dent Test; Smith, L.C. "On Brisance and a Plate-Denting Test for the Estimation of Detonation Pressure," Explosivstoffe no. 5, p 106 and no. 6, p 130 (1967).	Cast rod having a diameter greater than critical. Recommend L/D ≥ 3. Bare or confined.	No Range or Limit	21.3 GPa (calc.) $P_{CJ} = \rho_0 VOD^2(1 - 0.7125\rho_0^{0.04})$ P_{CJ} = Chapman-Jouget Pressure (steady-state detonation condition) ρ_0 = The un-reacted sample density VOD = velocity of detonation	RDX: 33.8 GPa TNT: 18.9 GPa

IMX-101 Qualification

	TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULT (RDX AND TNT)
15	**MISCELLANEOUS**					
15.1	SUSAN Impact Test †††	OD44811 TB 700-2 UN Test 7(c)(i)	0.45 kg SUSAN projectile launched at 333 m/s impacting on 64 mm thick steel plate	Pass = Average of 5 tests having air blast peak pressure < 3.9 psi	Pass 6 tests: Density Range = 1.66 – 1.67 g/cc Velocity Range = 340 – 365 m/s Average Pressure = 0.4 psi	RDX: N/A TNT: N/A

††† **Lot# BAE08K375-010**

Conclusions

• U. S. Army CLIMEx program was successful in identifying IMX-101 Explosive as a common insensitive replacement for TNT.

  •IMX-101 qualified by US Army as main charge explosive

• IM M795 155mm Munitions demonstrated far superior IM properties in all test categories with no barriers (BI, FI, SCO, FCO, SD, SCJI).

• IMX-101 meets M795 lethality requirements

• LAP of M795 Rounds using standard processing equipment was successfully developed and demonstrated with excellent cast quality.

• Safety Confirmation received for projectile

Conclusions (cont.)

• IMX-101 explosive is effectively a “drop-in” replacement for TNT in melt-cast LAP operations.

• BAE Systems at Holston AAP has robust manufacturing processes and essentially unlimited capacity for both the IM ingredients (i.e. DNAN, NTO, etc) and melt-cast formulations.

• The marvelous achievement of the CLIMEx program is a strong testimony of the dedication and teamwork of PM-CAS and its industry partners.